SIDIS at EIC

Sivers asymmetry simulations for eRHIC

INT workshop
Gluons and the quark sea at high energies

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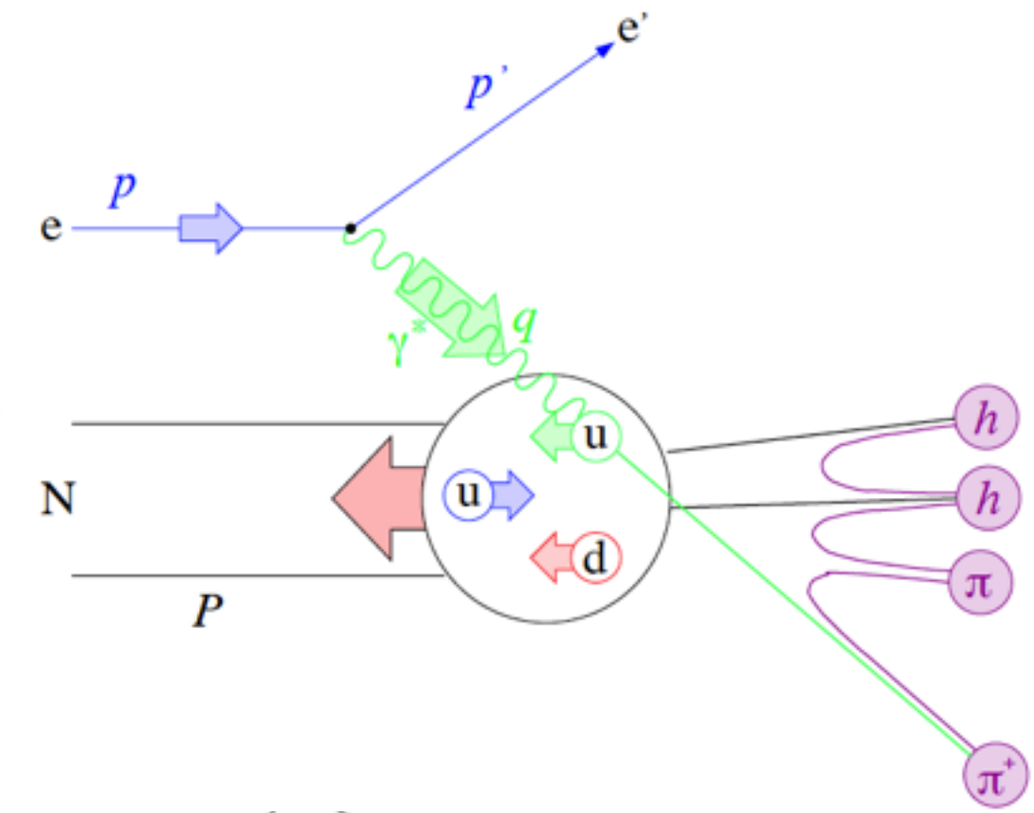
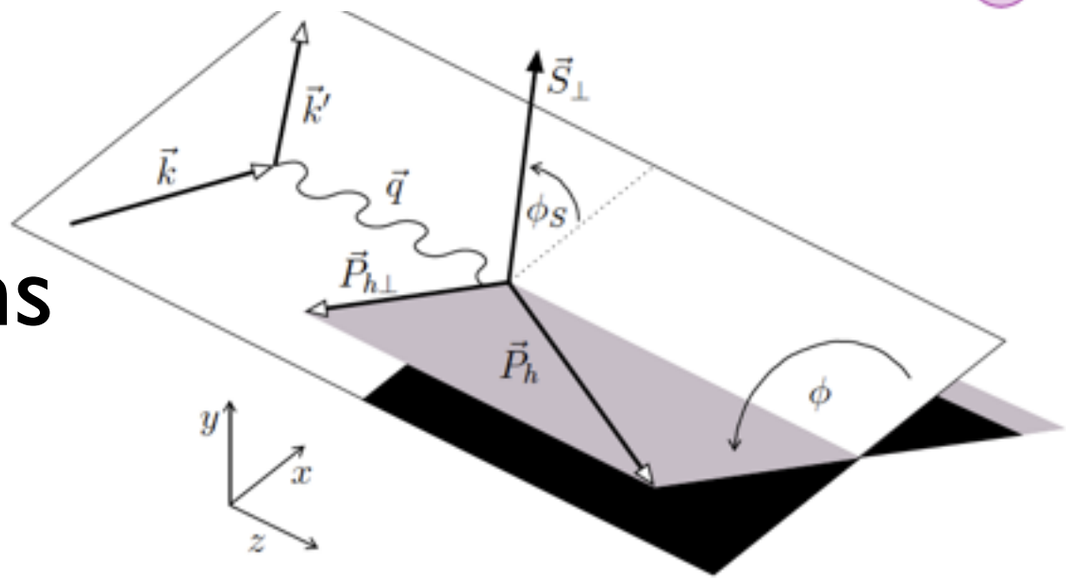
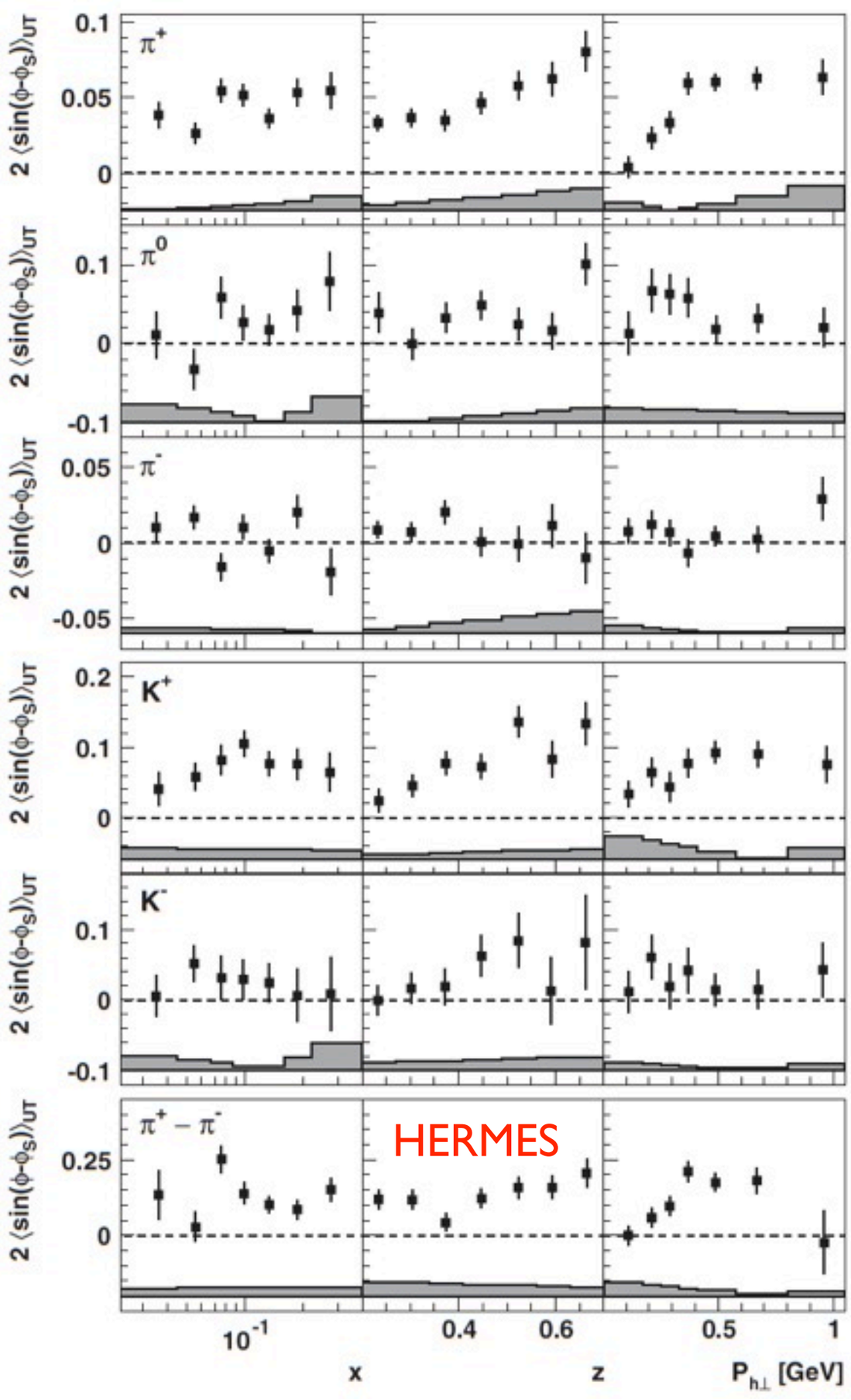
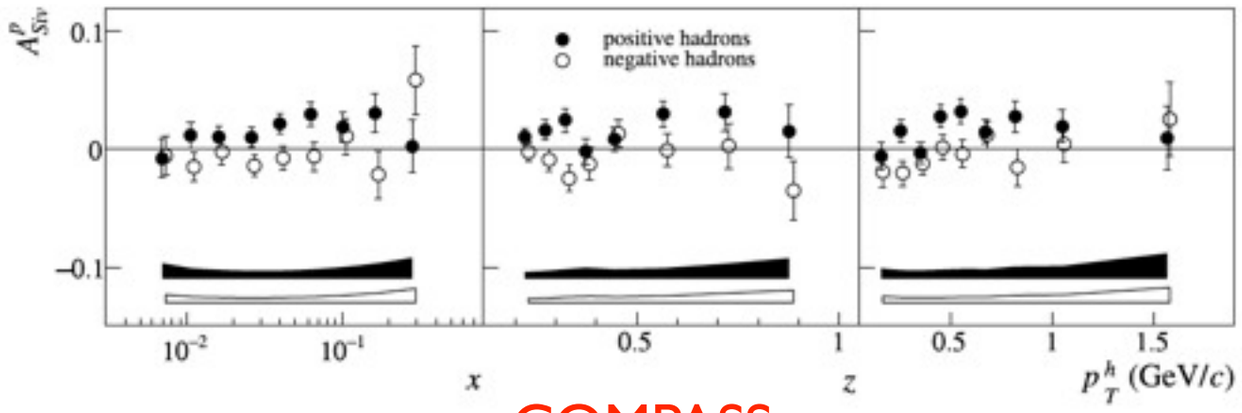
Overview

- Current status and EIC aims
- Kinematics:
  - **DIS**: Q^2 vs. x
  - **SIDIS**: z vs. $p_{h\perp}$
- Sivers asymmetry simulations

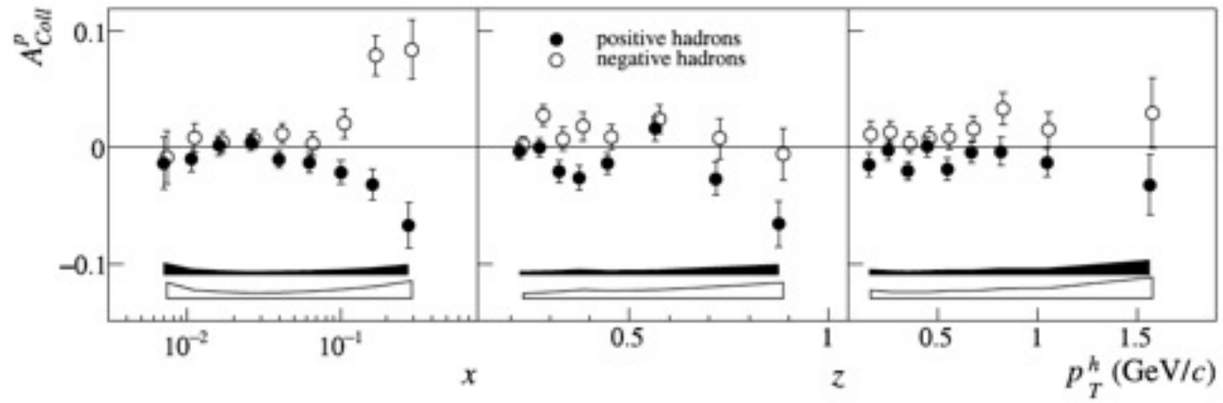








COMPASS



- But...
  - $x > 10^{-2}$
  - $p_{h\perp} < 1$ GeV/c
  - No high Q^2
  - 1D binning

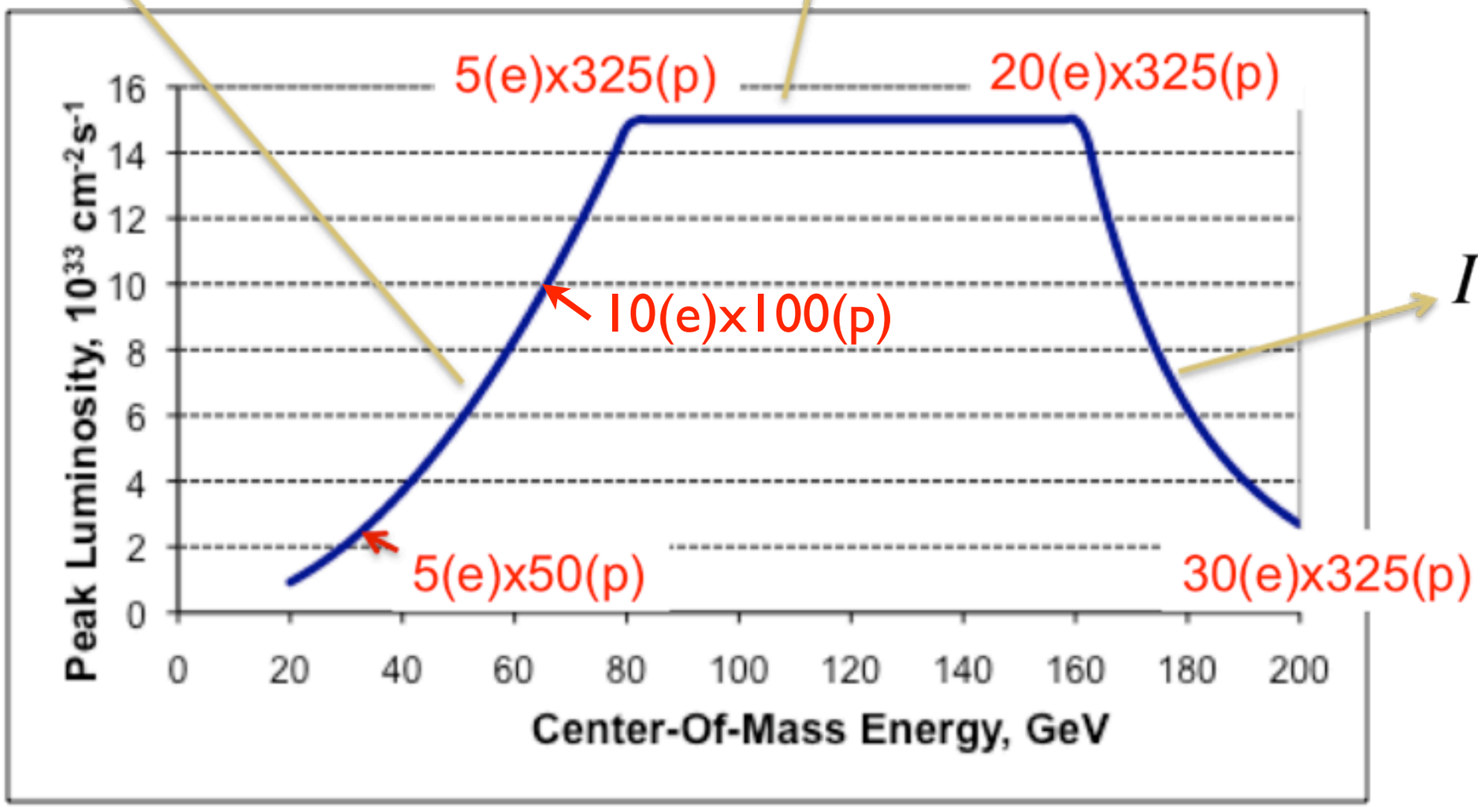
EIC aims

- Precise measurements with:
  - x vs. Q^2 range and **lever arm**
  - Larger $p_{h\perp}$
  - **Multidimensional** binning: Q^2, x, z, $p_{h\perp}$
- Requires the appropriate:
  - **Machine -** energy, luminosity
  - **Detector** - acceptance, resolution

Luminosity

IR magnet aperture should accommodate p beam size increase

Increased disruption (at low e energy) to be verified by beam-beam simulations



https://wiki.bnl.gov/eic/index.php/Luminosity

E_e GeV	E_p GeV	L ($cm^{-2}s^{-1}$)	$\int L$ (fb^{-1}) 1 month
5	50	0.3×10^{34}	4
10	100	1.0×10^{34}	13
20	250	1.4×10^{34}	20
30	325	0.3×10^{34}	4

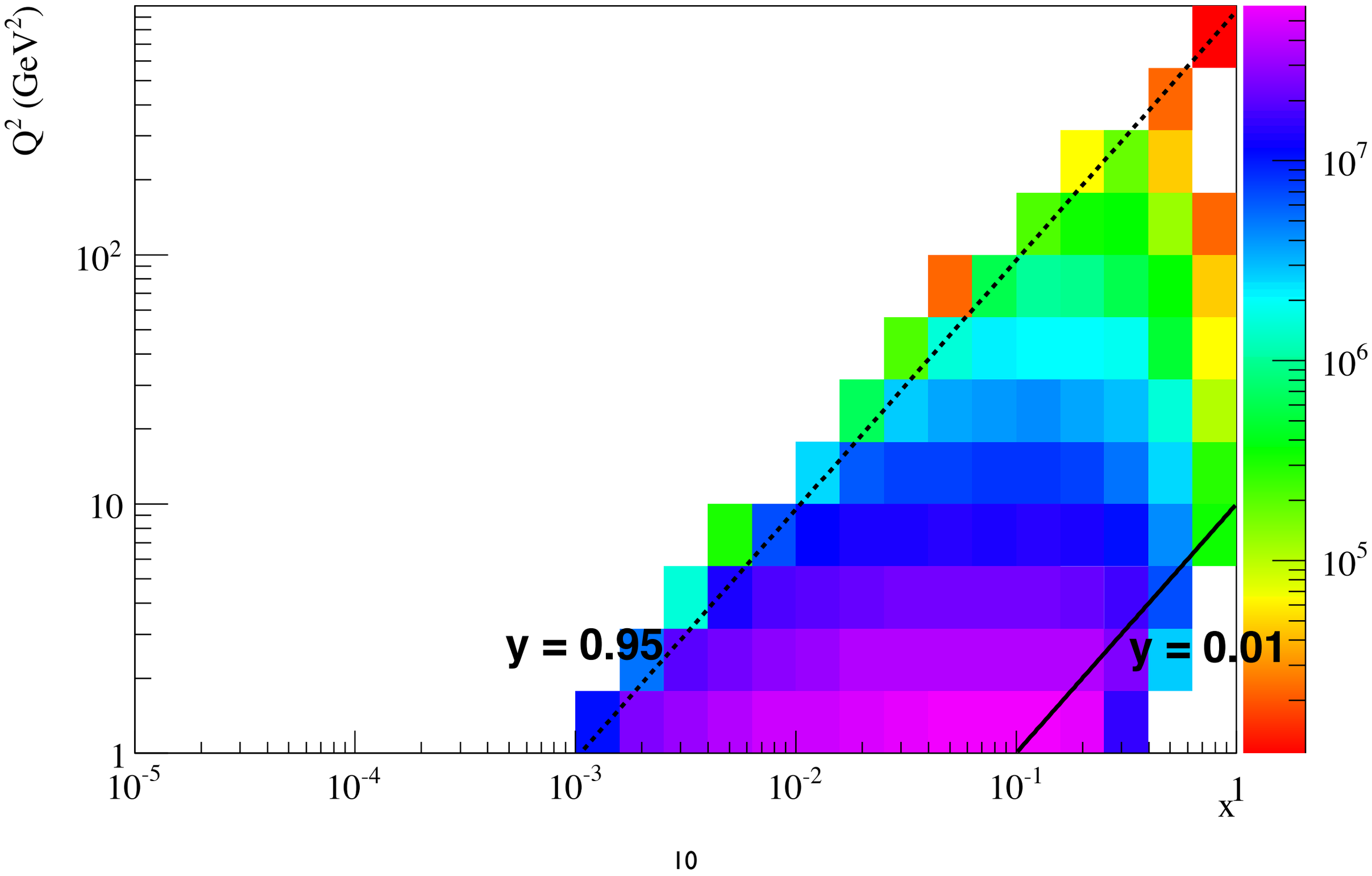
All plots assume these integrated luminosities

Q^2 vs. x

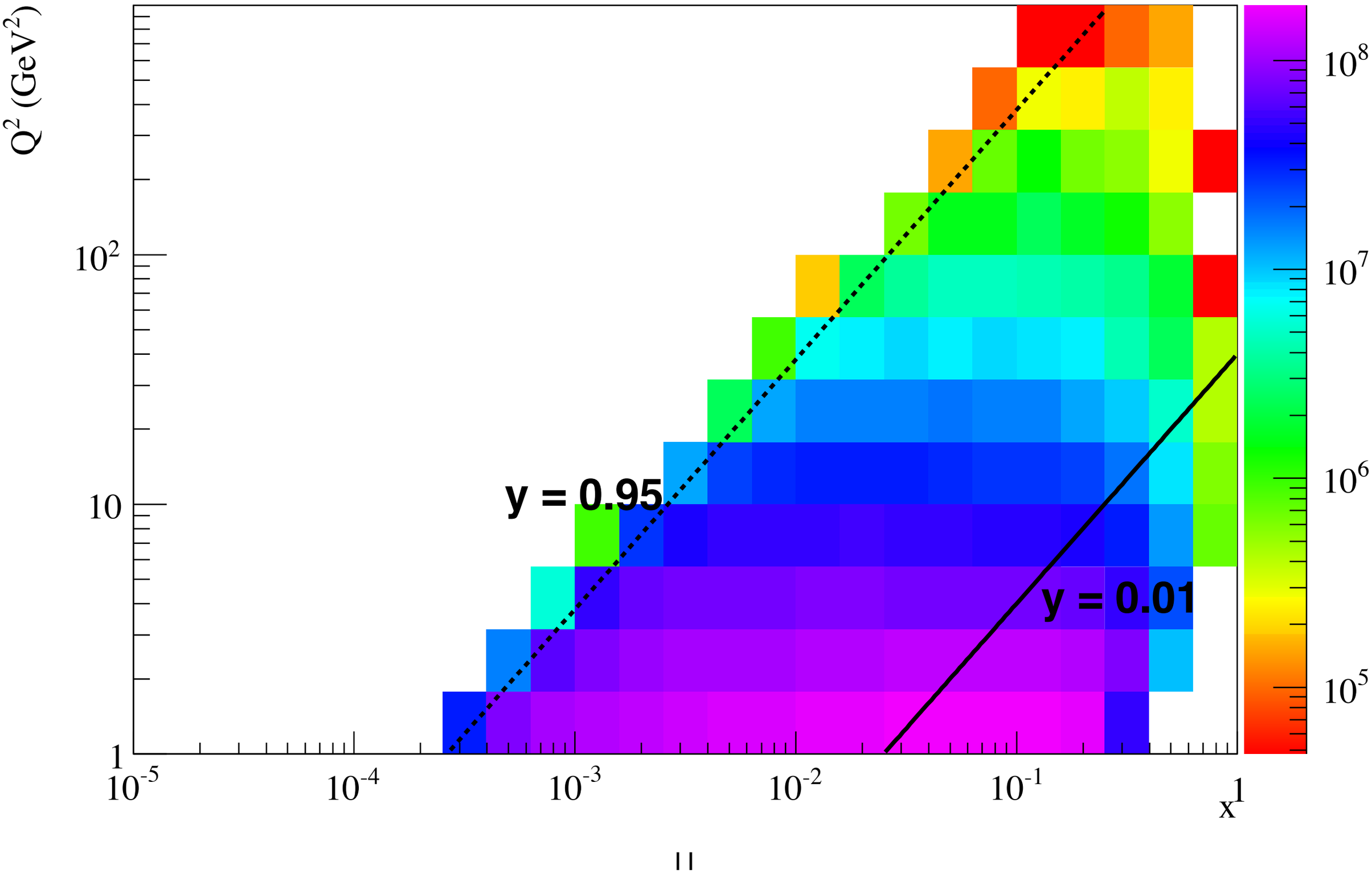
Simulation

- PYTHIA v6.4 (e + p)
- Subprocess 99 (LO DIS)
- Radiative corrections off
- Detector acceptance/resolution absent
- https://wiki.bnl.gov/eic/index.php/PYTHIA

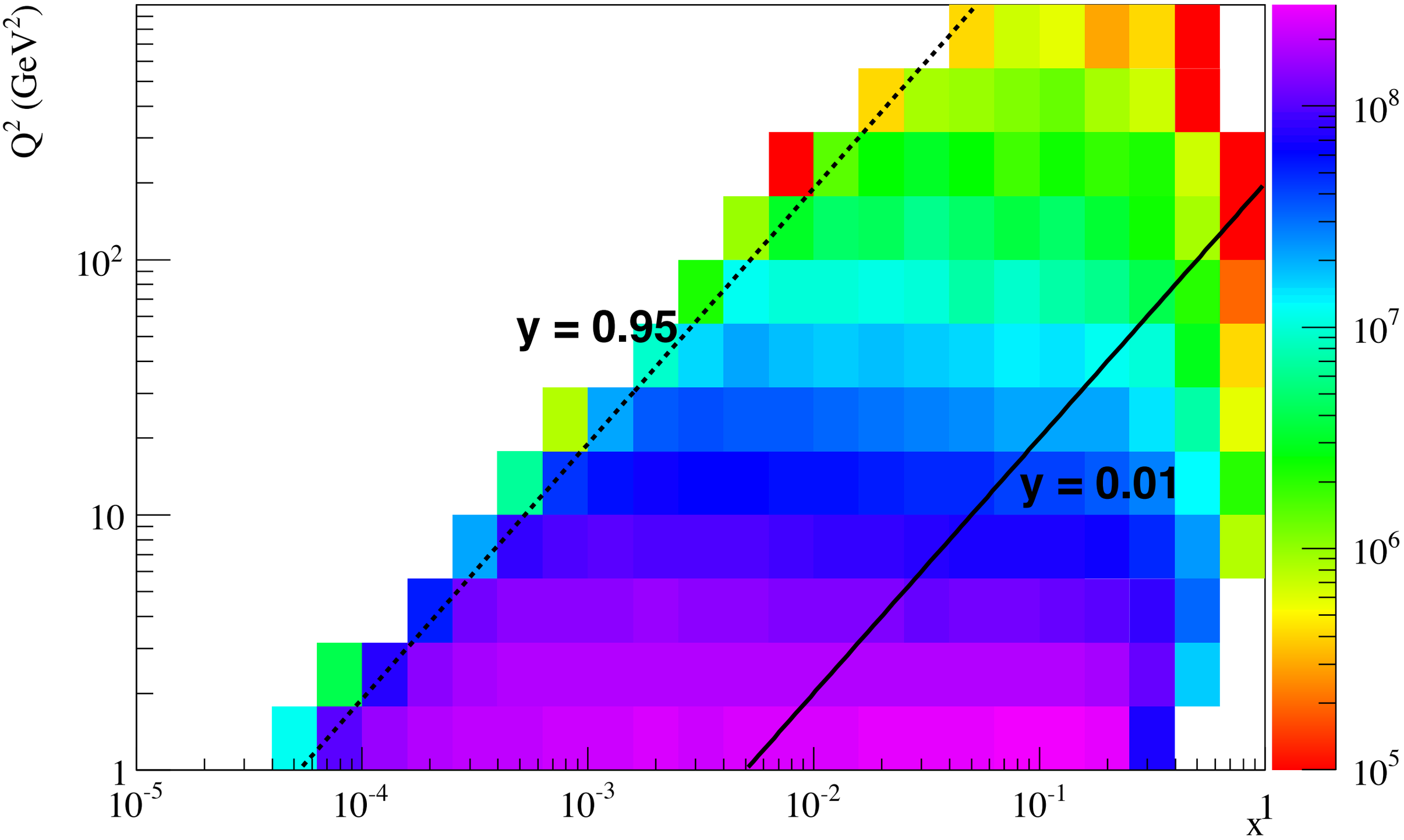
Q^2 vs. Bjorken x, 4 fb^{-1} at 5 x 50 GeV



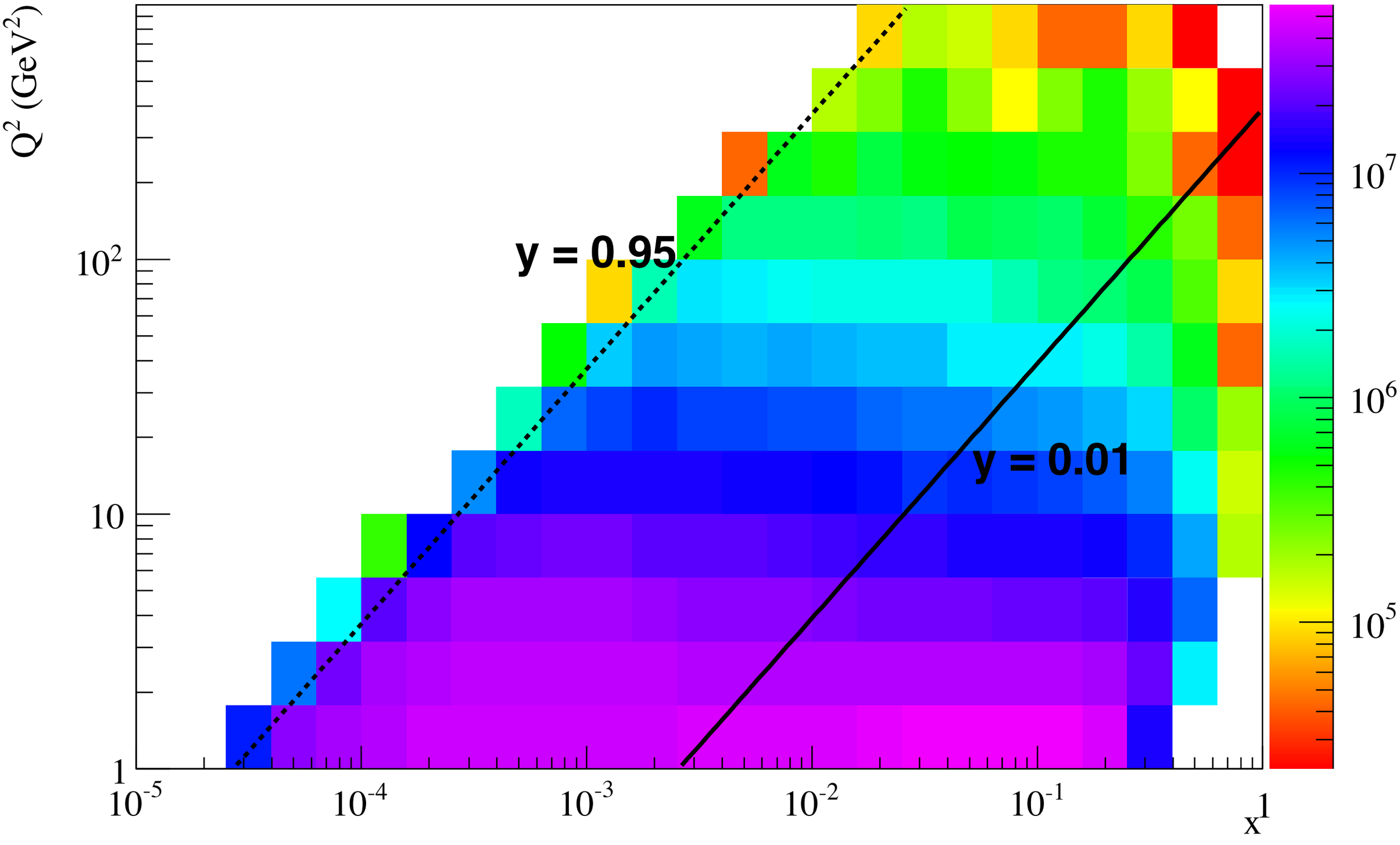
Q^2 vs. Bjorken x, 13 fb^{-1} at 10 x 100 GeV



Q^2 vs. Bjorken x, 20 fb^{-1} at 20 x 250 GeV



Q^2 vs. Bjorken x, 4 fb^{-1} at 30 x 325 GeV



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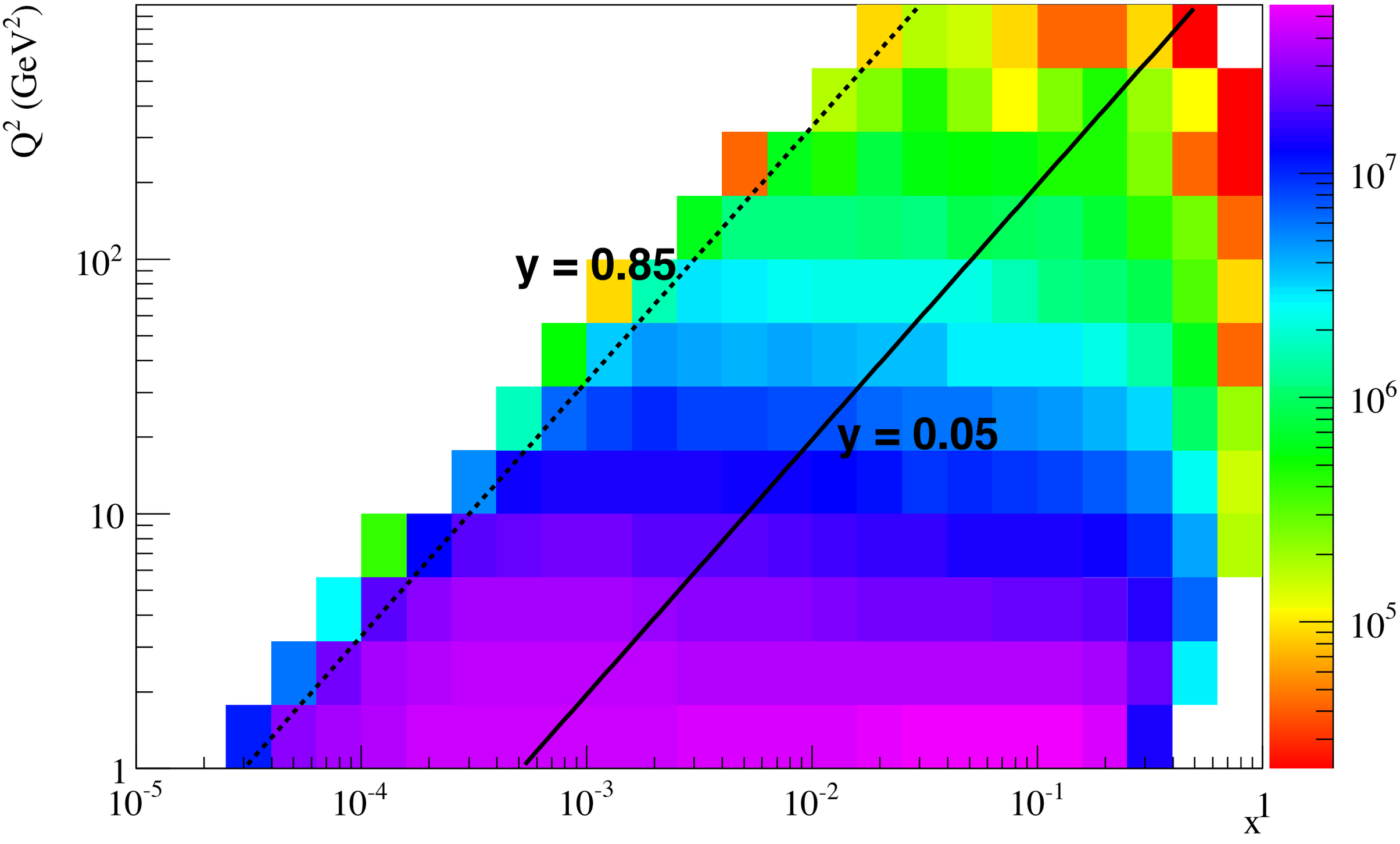
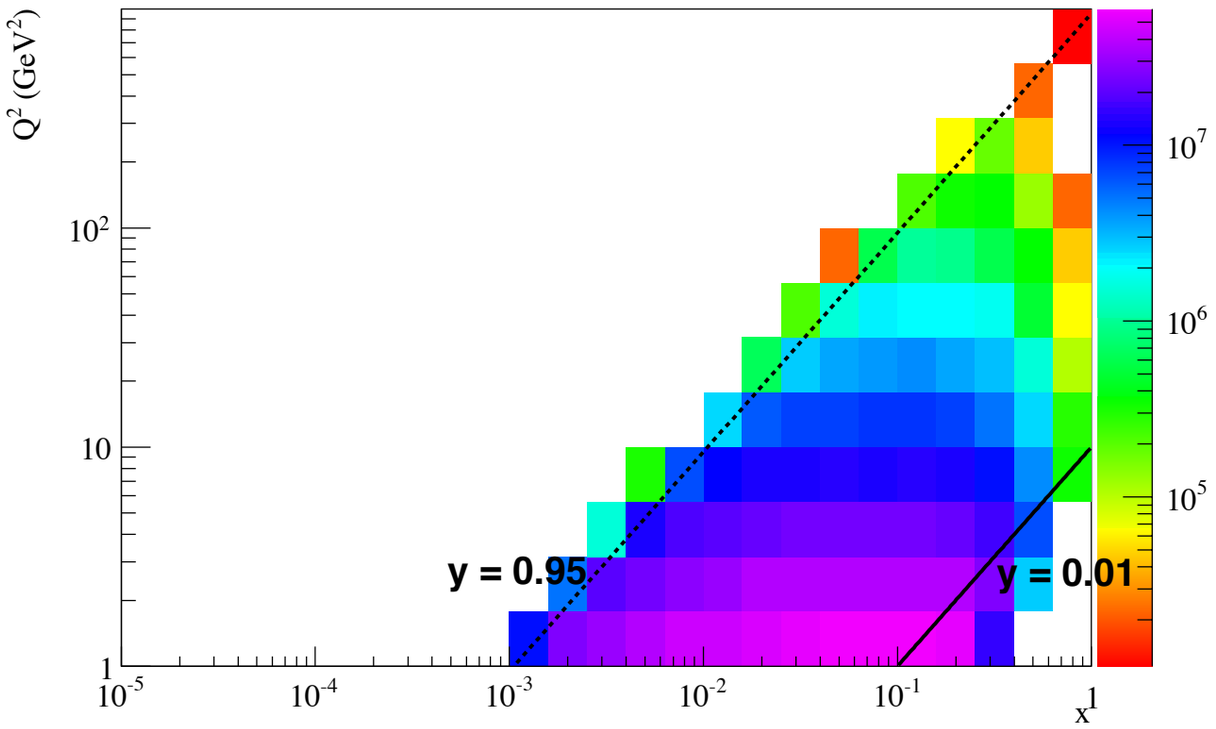


Q^2 vs. Bjorken x, 4 fb^{-1} at 5 x 50 GeV



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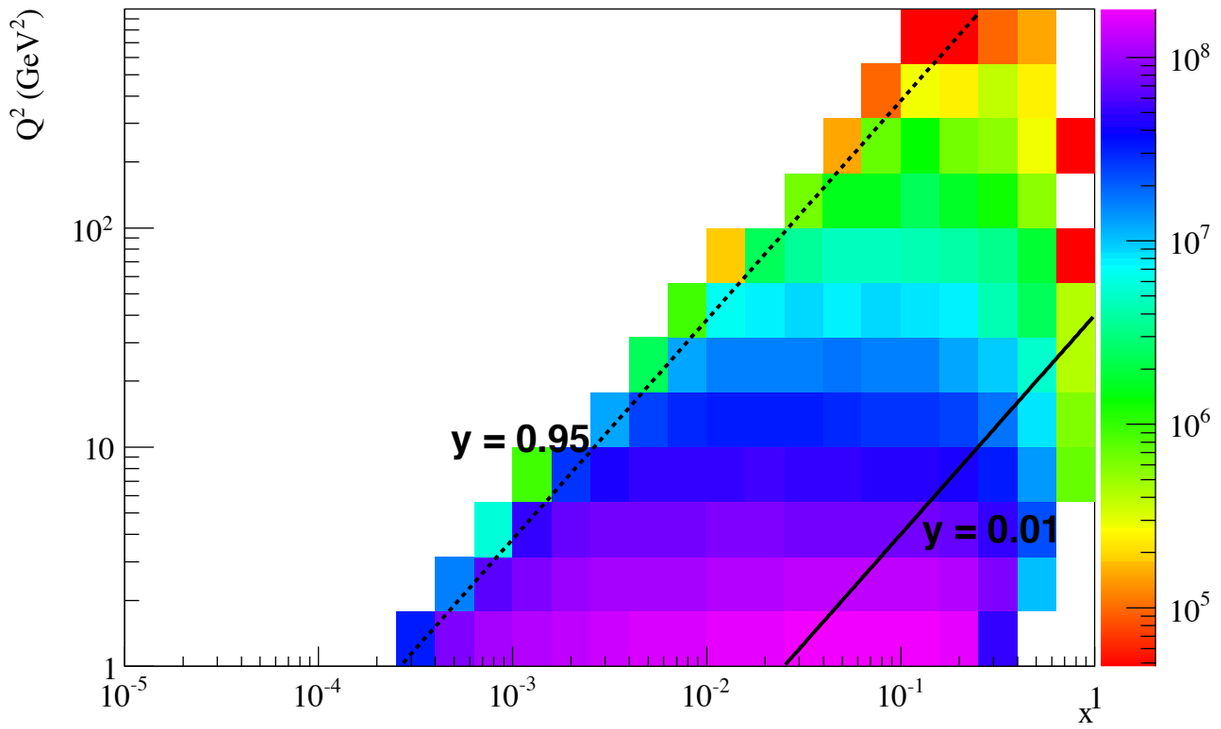
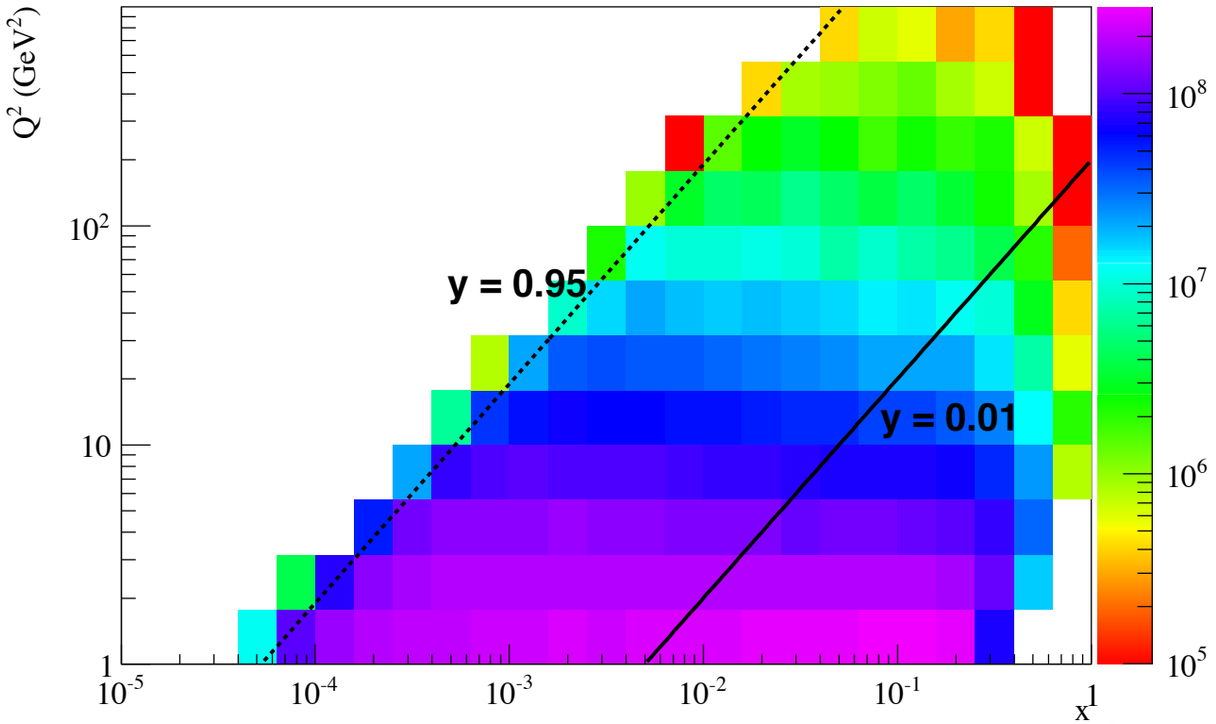
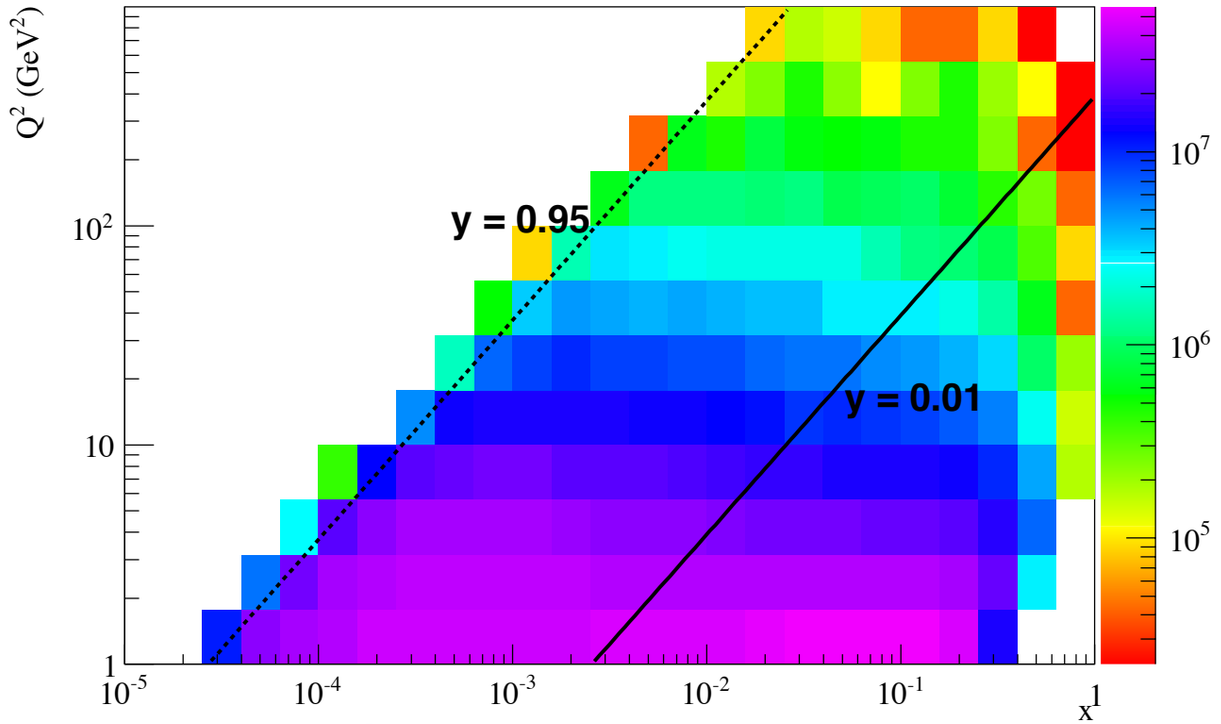


Q^2 vs. Bjorken x, 20 fb^{-1} at 20 x 250 GeV



Q^2 vs. Bjorken x, 4 fb^{-1} at 30 x 325 GeV



https://wiki.bnl.gov/eic/index.php/Kinematics

- Large statistics already with only 1 month
- Energy tunability maps Q^2 vs. x plane
- Q^2 lever arm
- Low y access useful

Q^2 bin progression

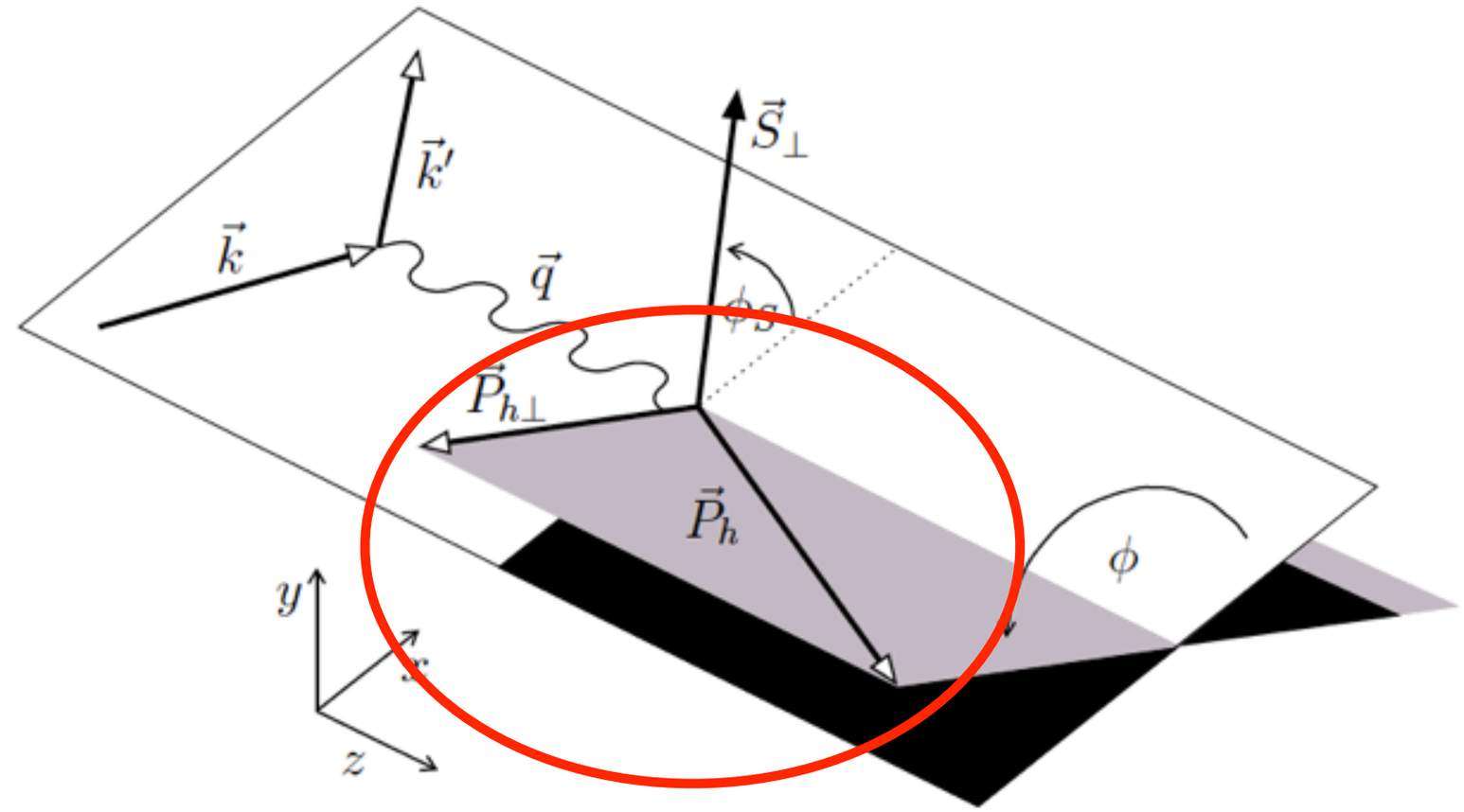
1	1.78
1.78	3.16
3.16	5.62
5.62	10

x bin progression

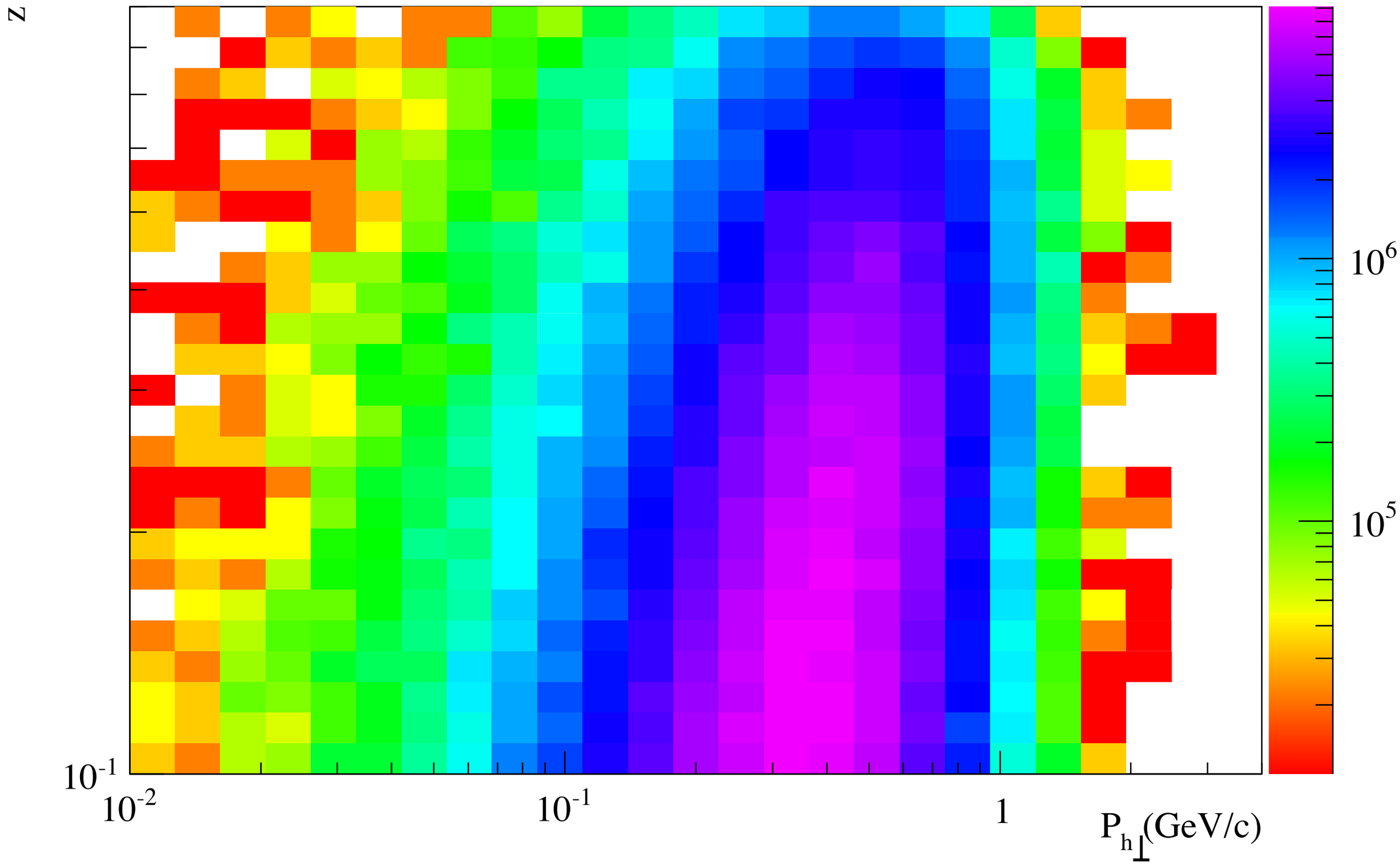
0.1	0.158
0.158	0.251
0.251	0.398
0.398	0.631
0.631	1

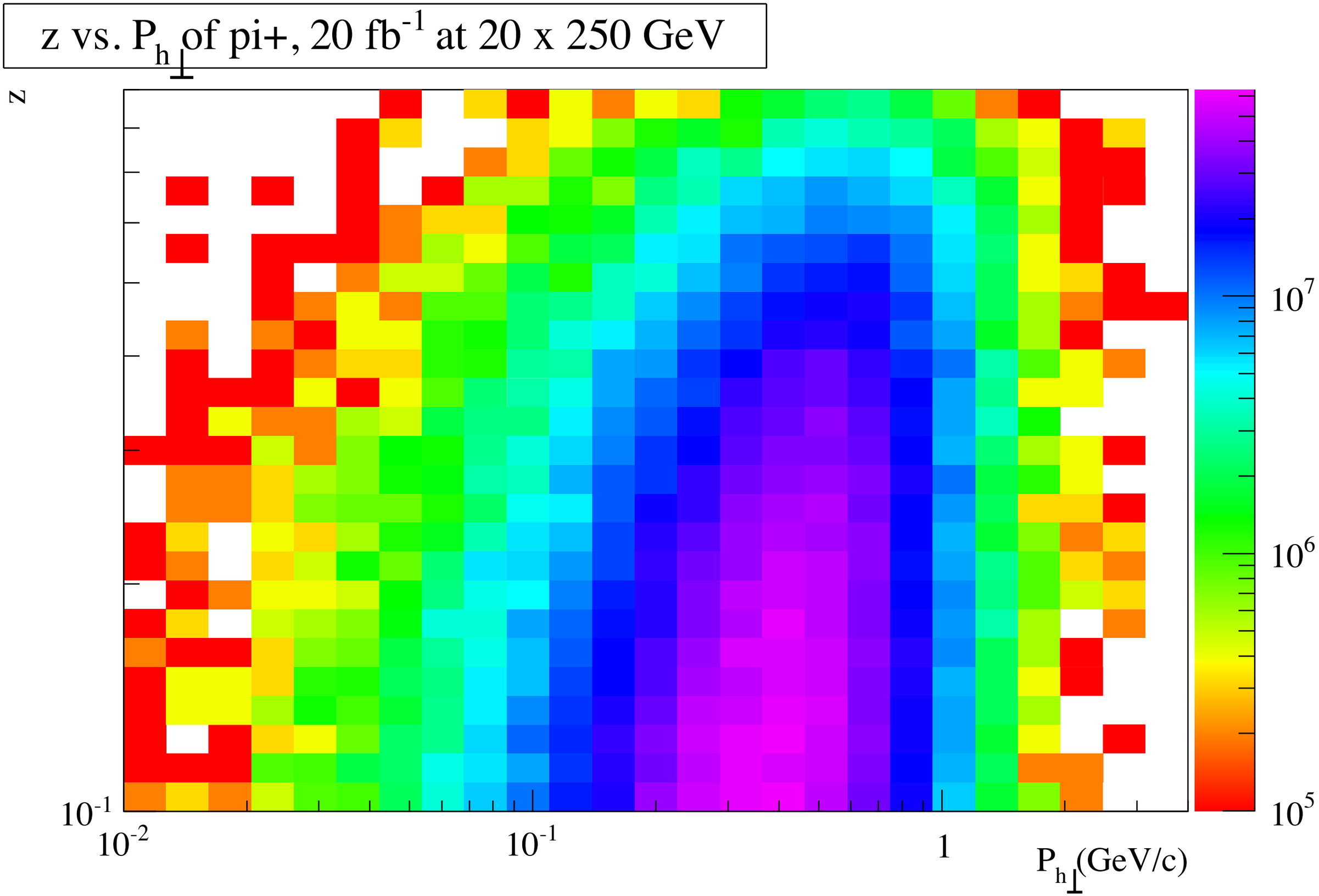
z vs. $p_{h\perp}$

- PYTHIA v6.4
- $Q^2 > 1\ GeV^2$
- $0.01 < y < 0.95$

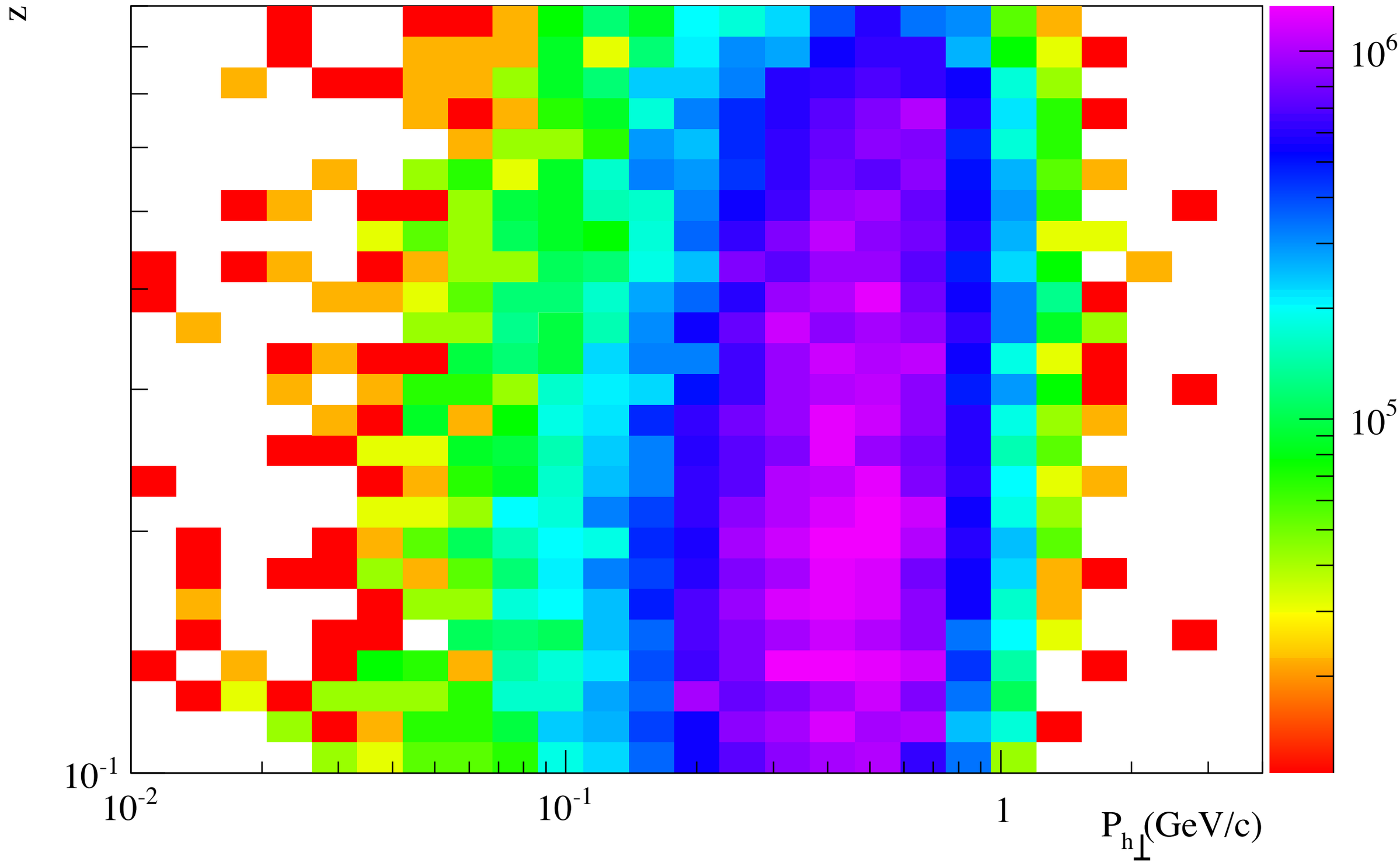


z vs. $P_{h\perp}$ of pi+, 4 fb^{-1} at 5 x 50 GeV

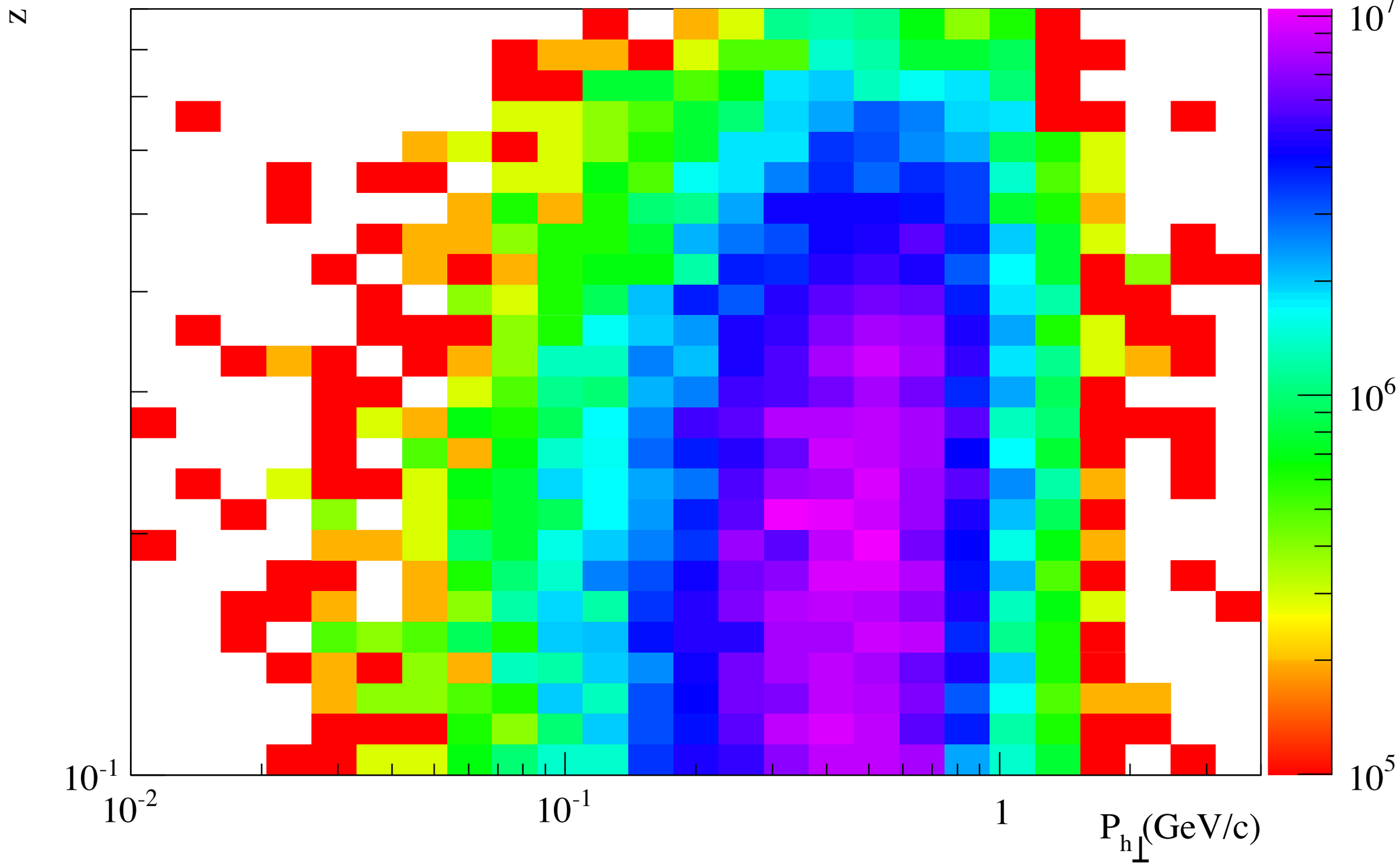



z vs. $P_{h\perp}$ of pi+, 20 fb^{-1} at 20 x 250 GeV
z
10^{-1}
10^{-2}
10^{-1}
1
$P_{h\perp}$(GeV/c)
10^{7}
10^{6}
10^{5}

z vs. $P_{h\perp}$ of K+, 4 fb^{-1} at 5 x 50 GeV

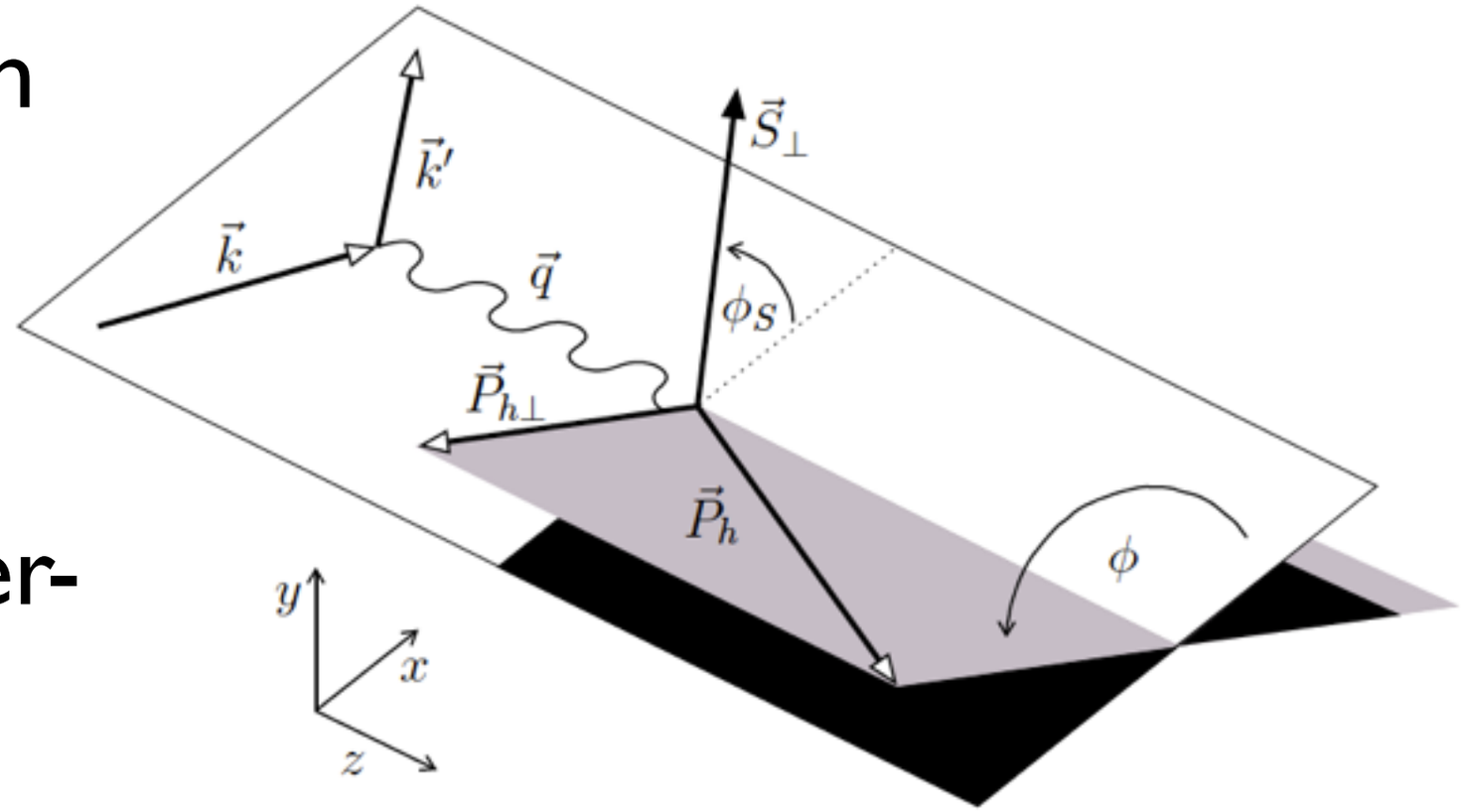


z vs. $P_{h\perp}$ of K+, 20 fb^{-1} at 20 x 250 GeV



gmc_trans

- Throws events via SIDIS cross section
- e + p → e` + h [$\pi^{+/-/0}$, $K^{+/-}$ or p]
- Sivers, Collins, Boer-Mulders
- No gluon TMDs



Setup

https://wiki.bnl.gov/eic/index.php/Gmc_trans

- Unpolarised PDF: ***CTEQ6L***
- Polarised PDF: ***DSSV***
- Fragmentation functions: ***DSS***
- $0.01 < y < 0.95$
- $0.1 < z < 0.9$

Simple parameterisation

- Don't know low-x Sivers
- $f_{1T}^{\perp} \propto f_1$
- Limit to lower x < 0.1
- 30 days @ 50% operational efficiency

$u_{1T}^{\perp}$	$d_{1T}^{\perp}$	$s_{1T}^{\perp}$
-0.1u	0.1d	0.1s
-0.1u	0.1d	0

i.e. Investigate how easily can we distinguish significant vs. zero effects

- 2 representative luminosities/energies:
  - 4 fb^{-1} at 5 x 50 GeV
  - 20 fb^{-1} at 20 x 250 GeV
- 2 representative hadrons:
  - π^+ and K^+

5 x 50 GeV

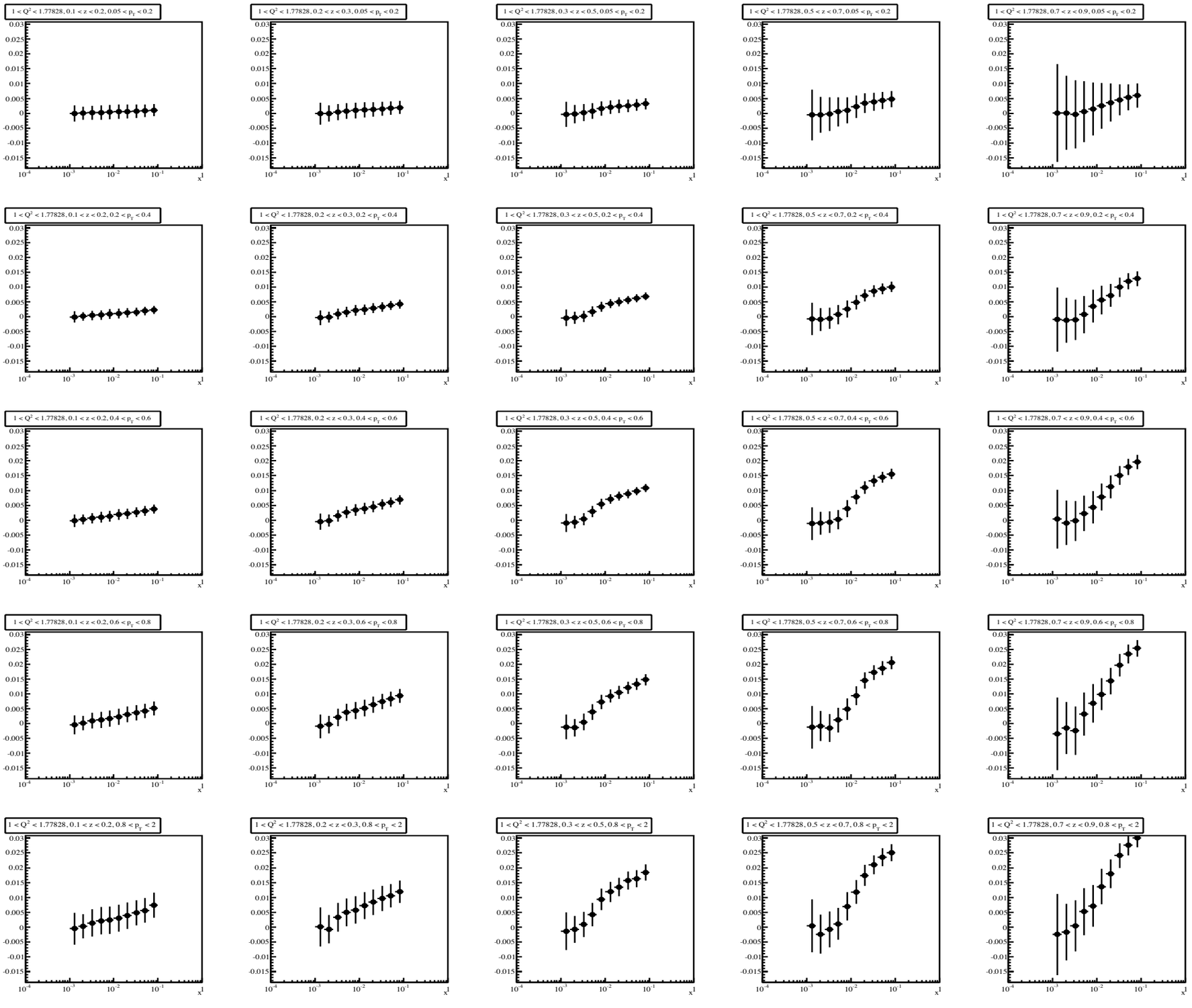
$1 < Q^2 < 1.78\ \mathrm{GeV}^2$

π^+

$A_{UT}^{\sin\phi_S}$

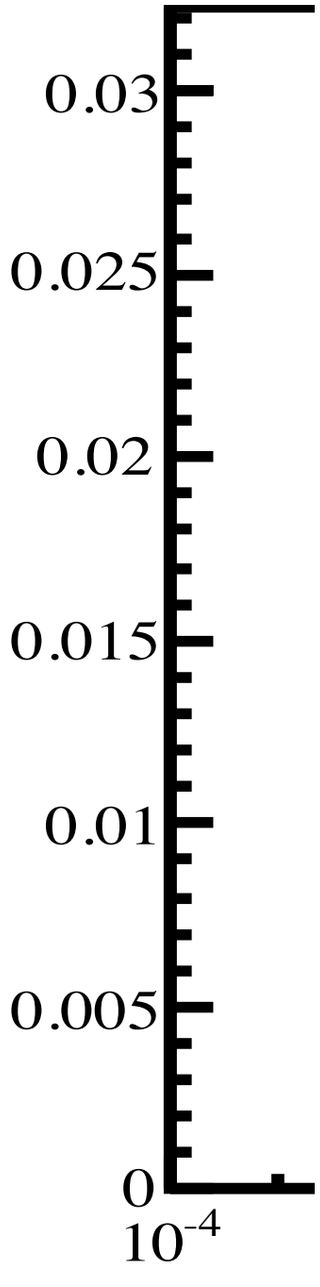
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015

10^{-4}



$10 < Q^2 < 17.8\ \mathrm{GeV}^2$

π^+



$0.005 < P_{h\perp} < 0.2$

$0.2 < P_{h\perp} < 0.4$

$0.4 < P_{h\perp} < 0.6$

$0.6 < P_{h\perp} < 0.8$

$0.8 < P_{h\perp} < 2$

$0.1 < z < 0.2$ $0.2 < z < 0.3$ $0.3 < z < 0.5$ $0.5 < z < 0.7$ $0.7 < z < 0.9$

$1 < Q^2 < 1.78\ GeV^2$ +ve Sea No sea

π^+

$A_{UT}^{\sin\phi_S}$

0.03
0.025
0.02
0.015
0.01
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0
-0.005
-0.01
-0.015
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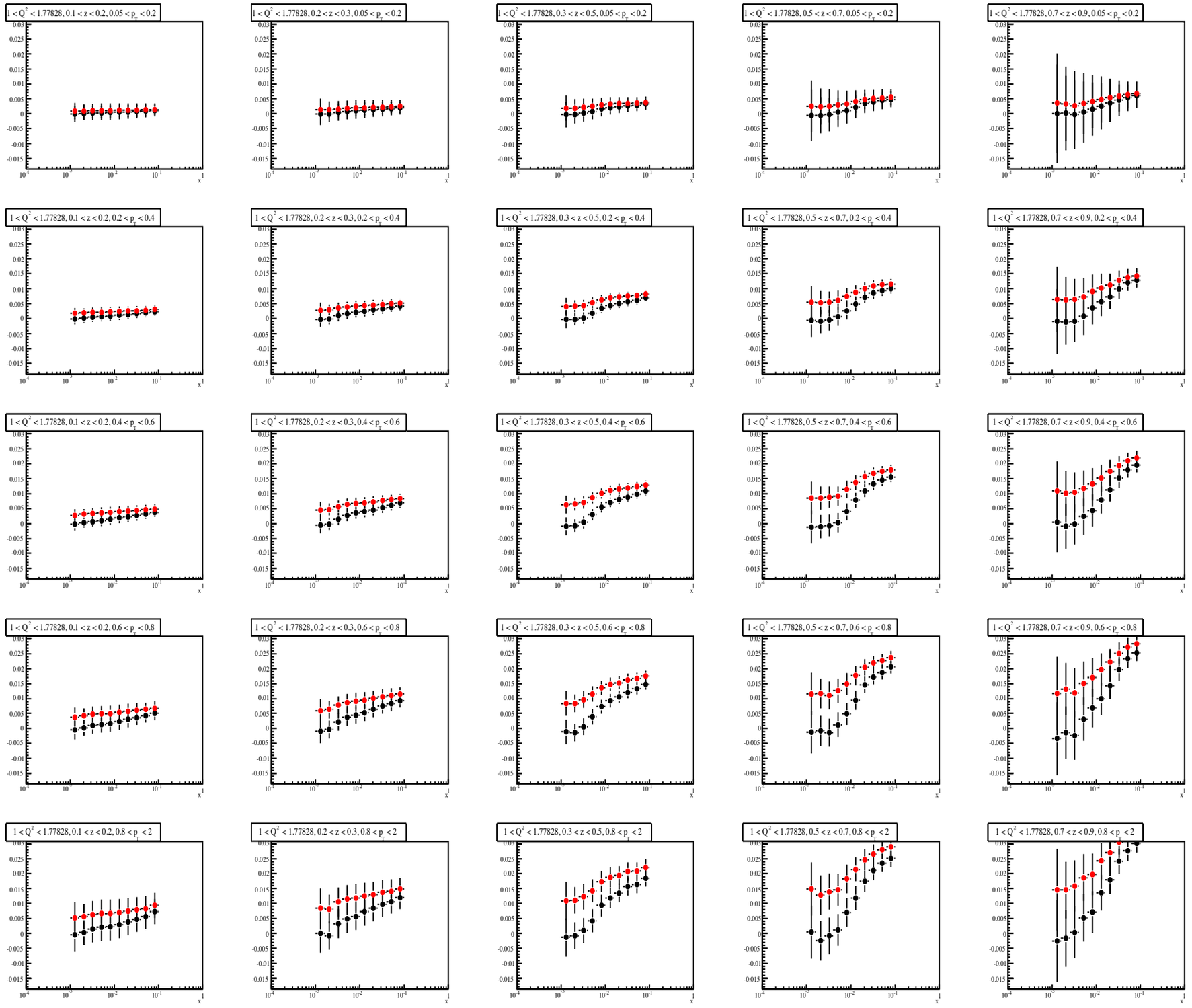

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$0.4 < P_{h\perp} < 0.6$
$0.6 < P_{h\perp} < 0.8$
$0.8 < P_{h\perp} < 2$

$1 < Q^2 < 1.78\ \mathrm{GeV}^2$

K^+

$A_{UT}^{\sin\phi_S}$

0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015

10^{-4}

$0.005 < P_{h\perp} < 0.2$

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$0.1 < z < 0.2$

$0.2 < z < 0.3$

$0.3 < z < 0.5$

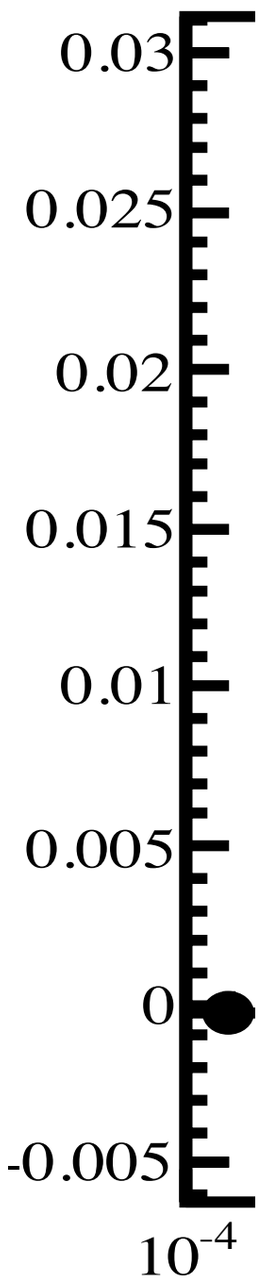
$0.5 < z < 0.7$

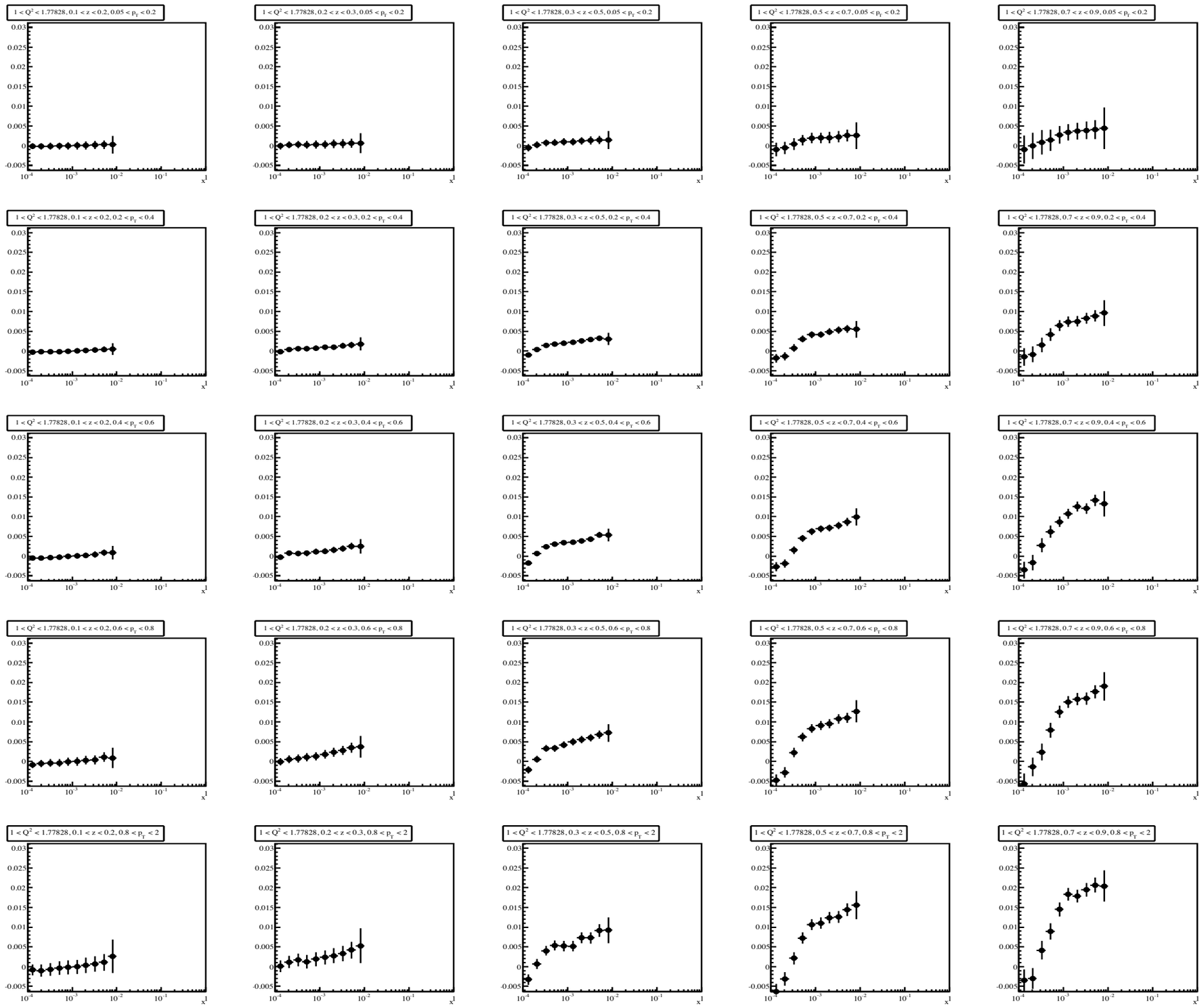
$0.7 < z < 0.9$

20 x 250 GeV

$1 < Q^2 < 1.78\ \mathrm{GeV}^2$

π^+





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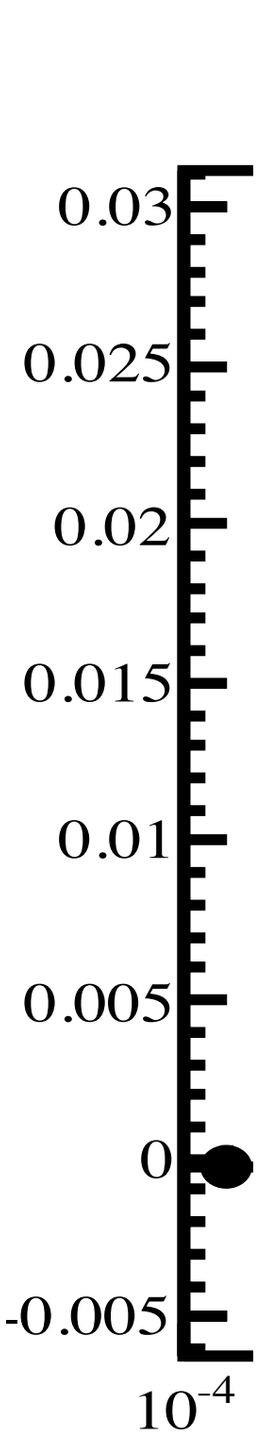
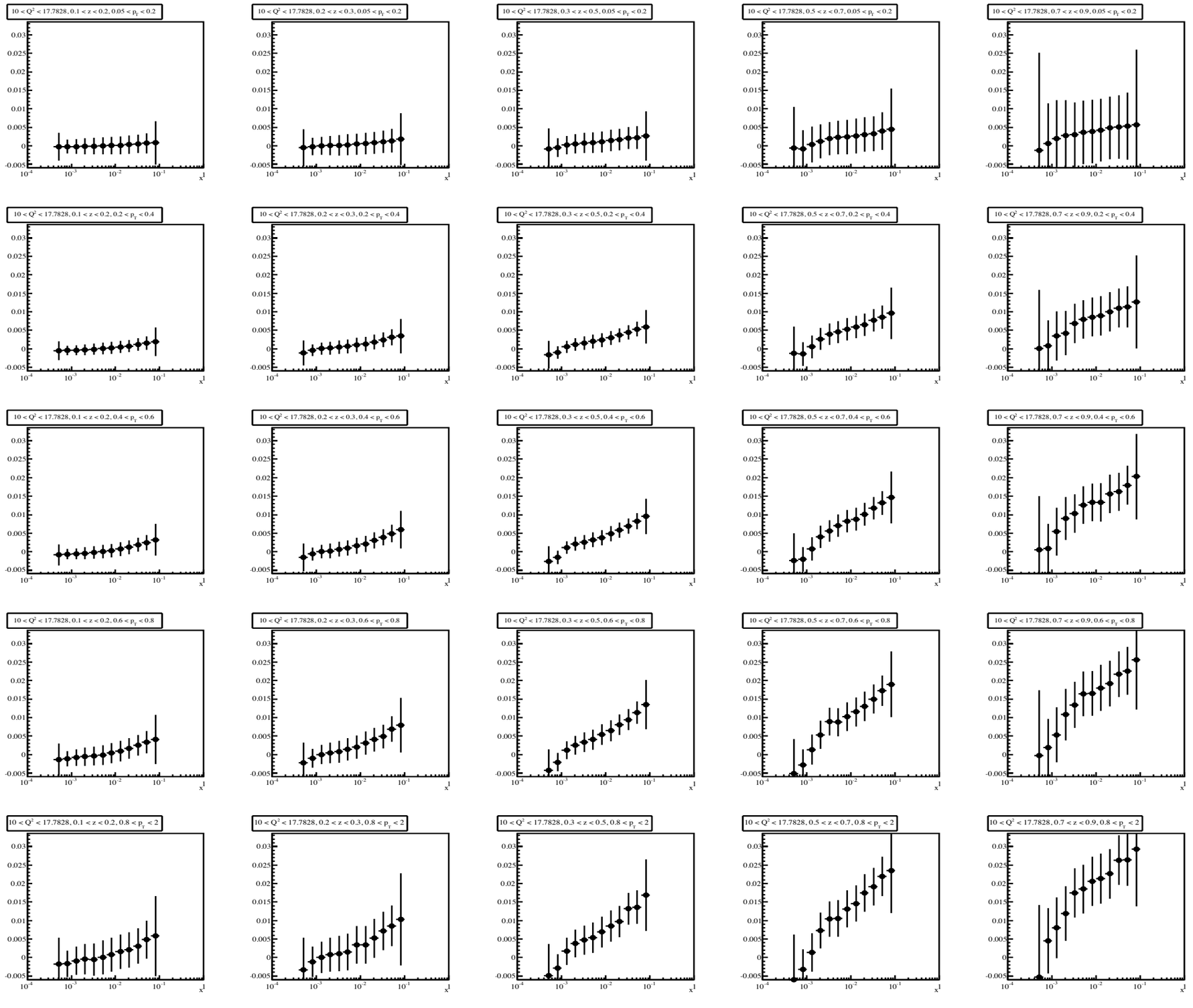
$10 < Q^2 < 17.8\ \mathrm{GeV}^2$

π^+





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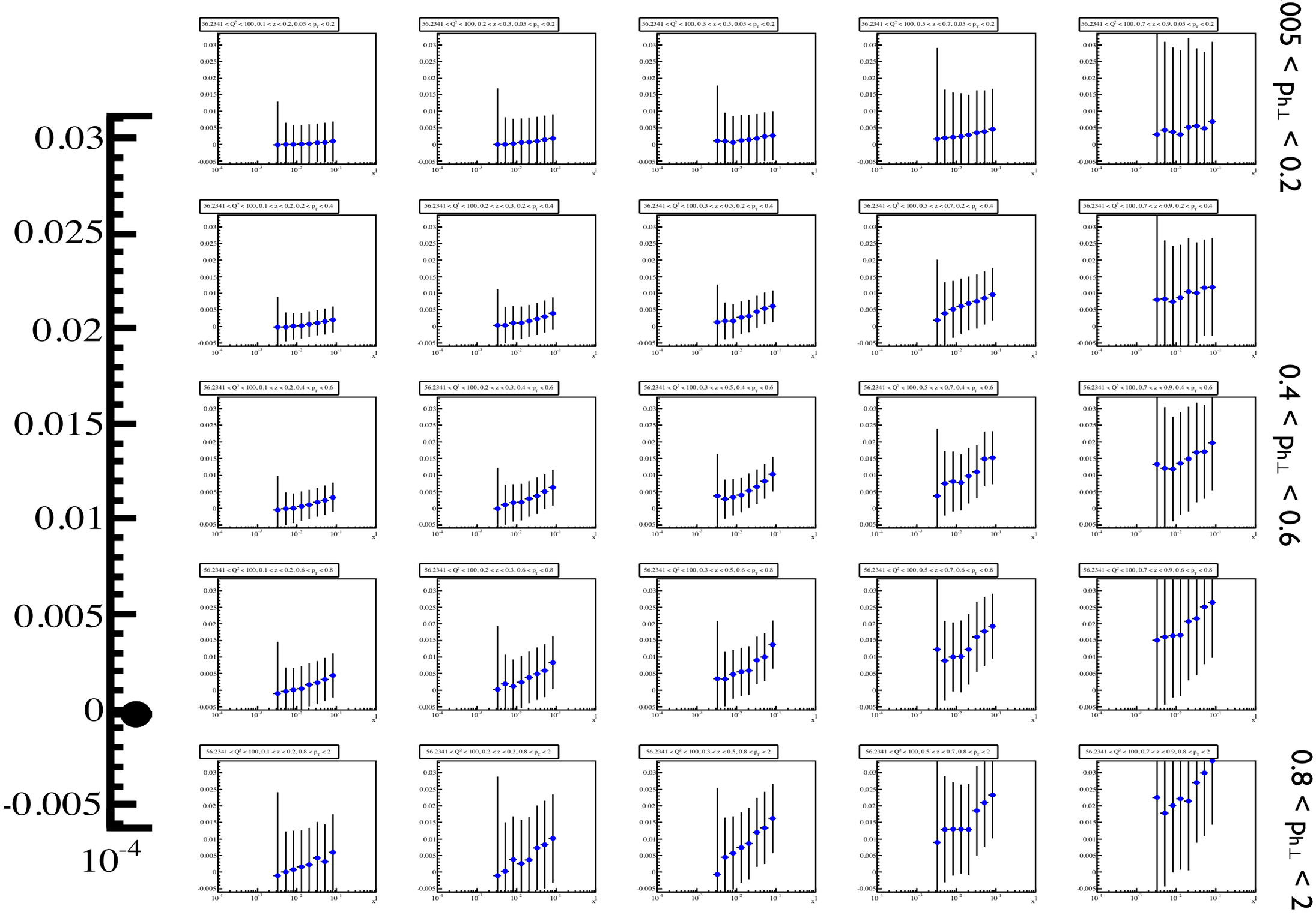
$0.1 < z < 0.2$ $0.2 < z < 0.3$ $0.3 < z < 0.5$ $0.5 < z < 0.7$ $0.7 < z < 0.9$

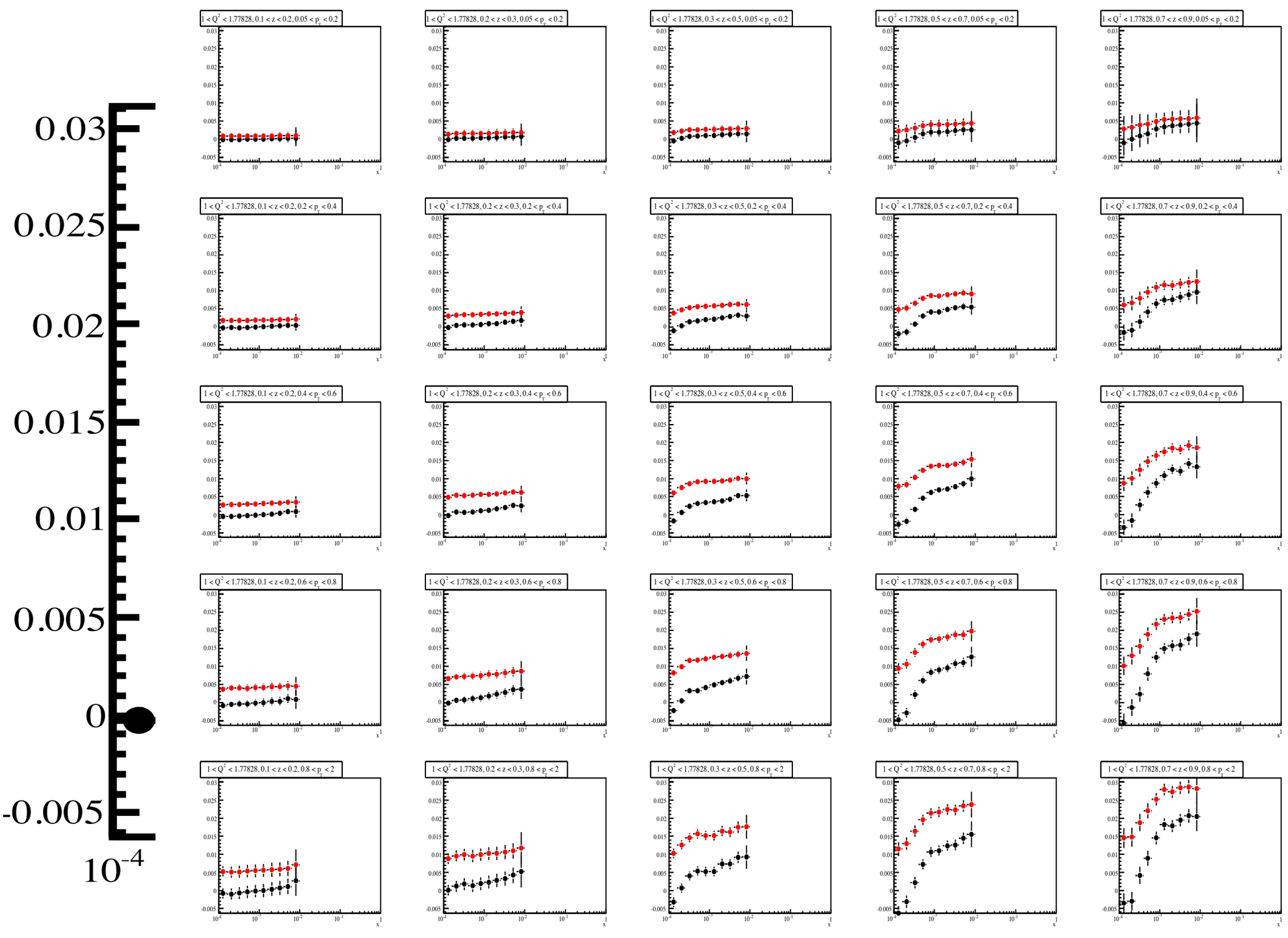
$56.2 < Q^2 < 100\ \text{GeV}^2$

π^+



$1 < Q^2 < 1.78\ GeV^2$ +ve Sea No sea

π^+



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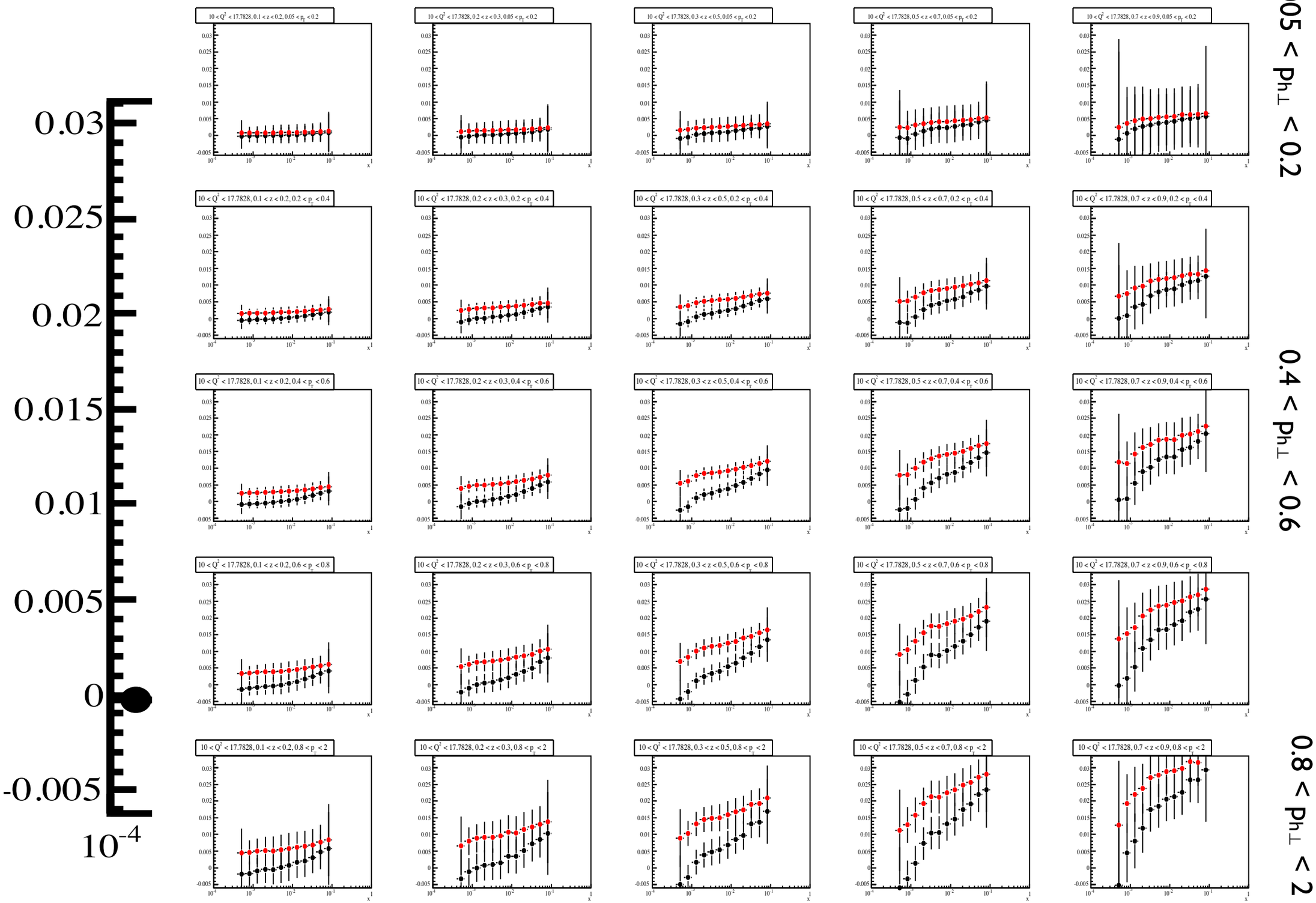
$10 < Q^2 < 17.8\ GeV^2$ +ve Sea No sea

π^+



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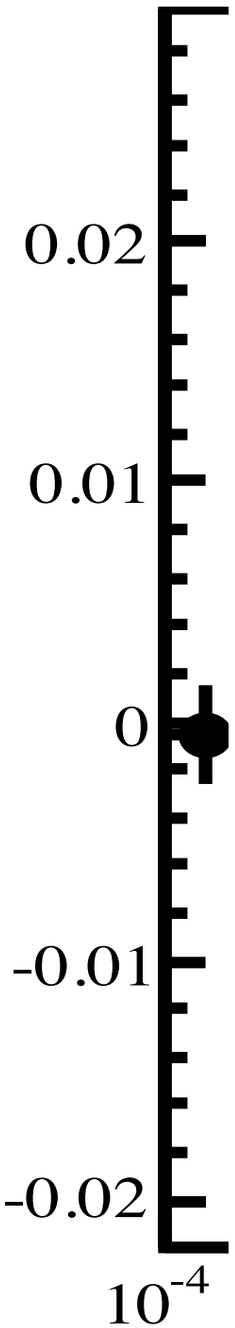
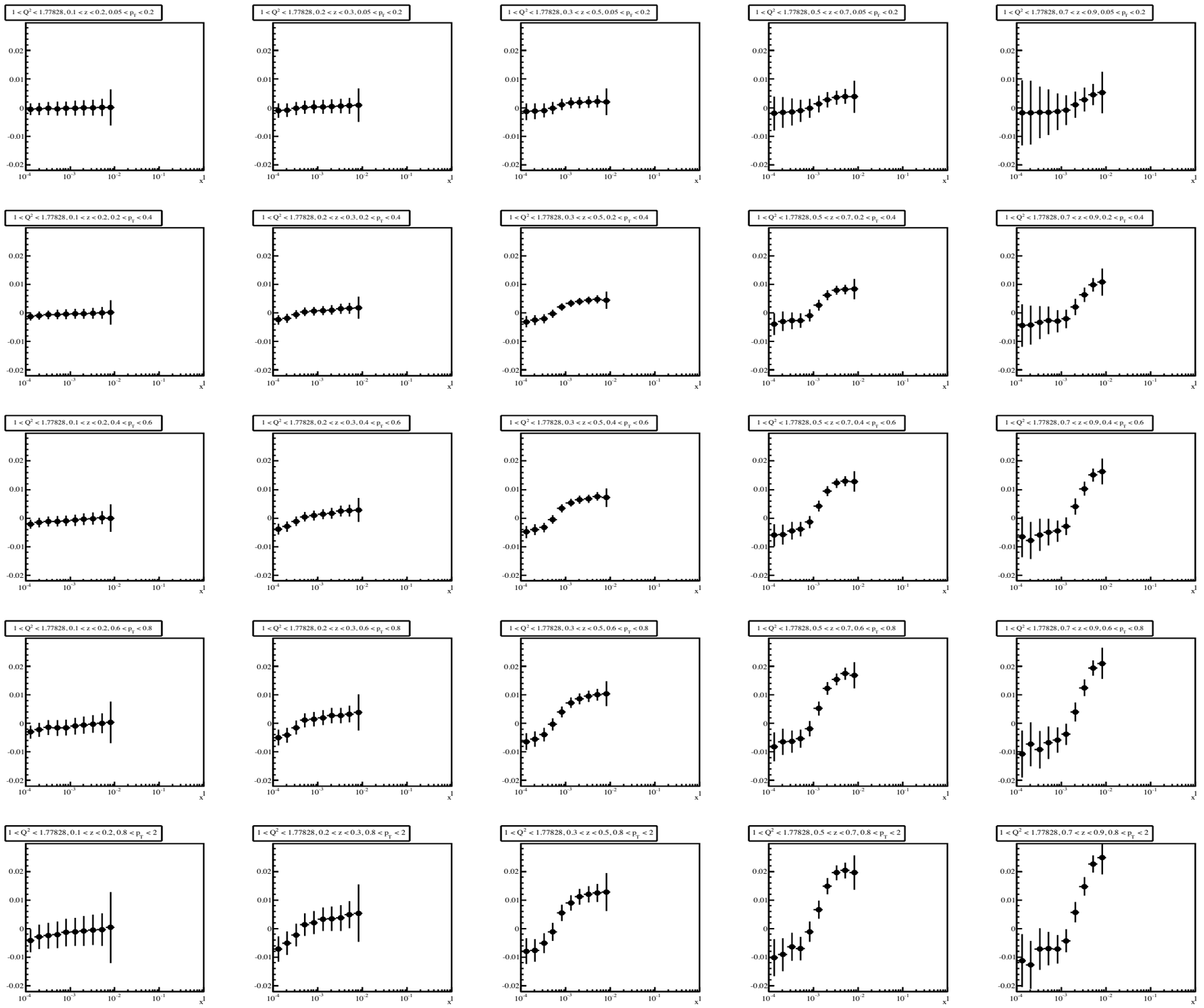
K^+





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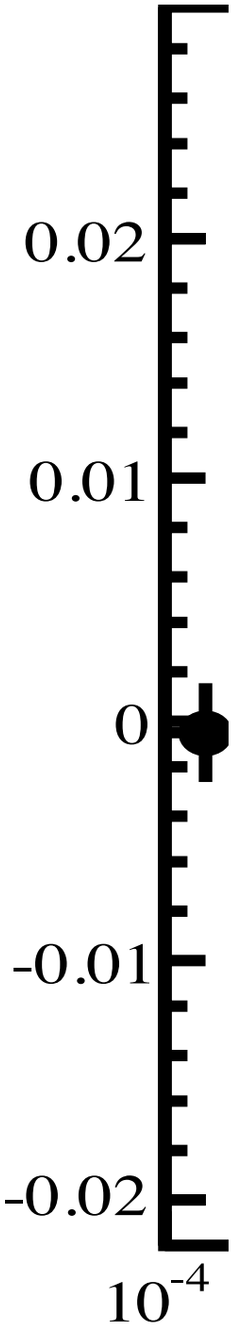
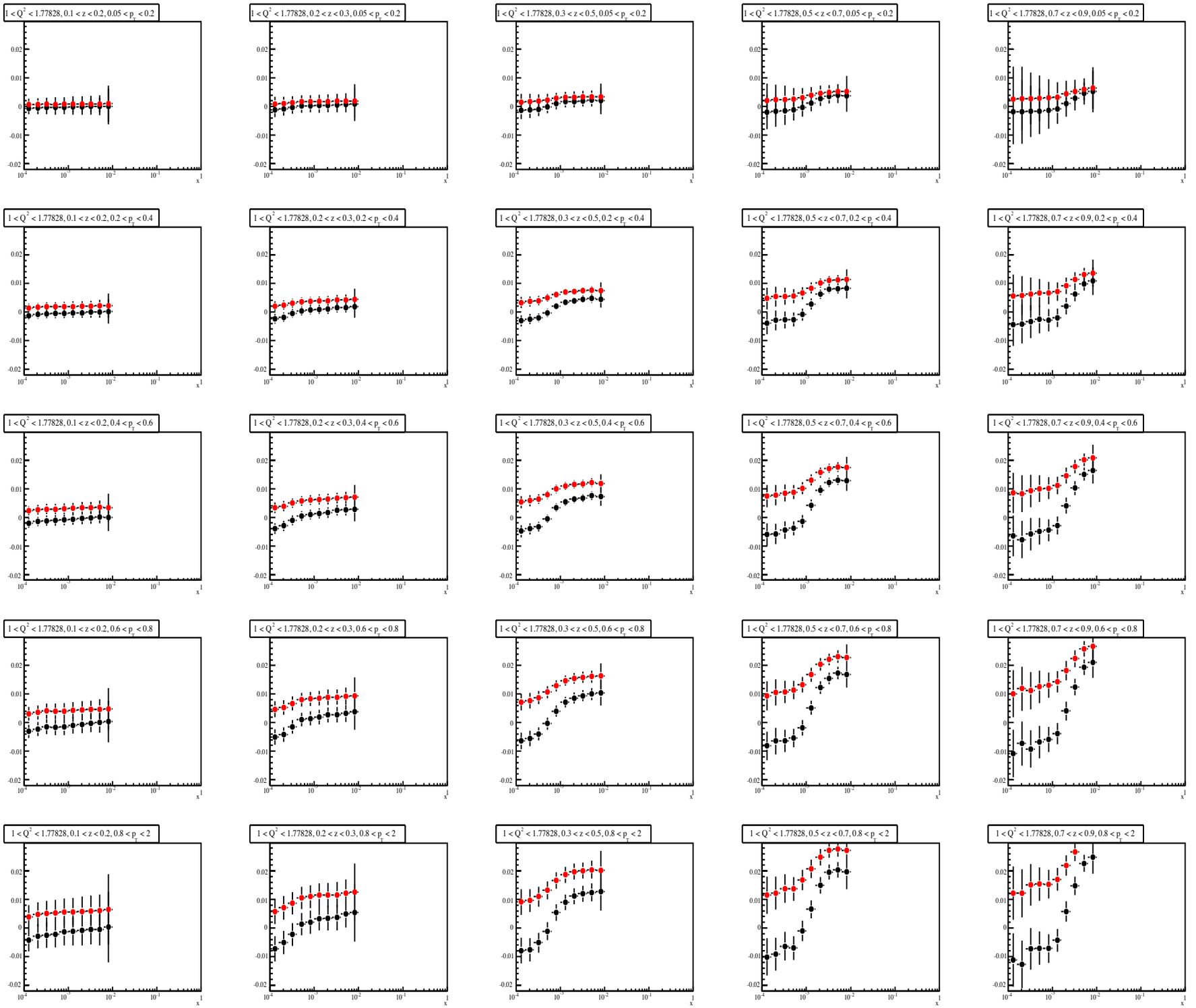
K^+





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$0.005 < P_{h\perp} < 0.2$

$0.2 < P_{h\perp} < 0.4$

$0.4 < P_{h\perp} < 0.6$

$0.6 < P_{h\perp} < 0.8$

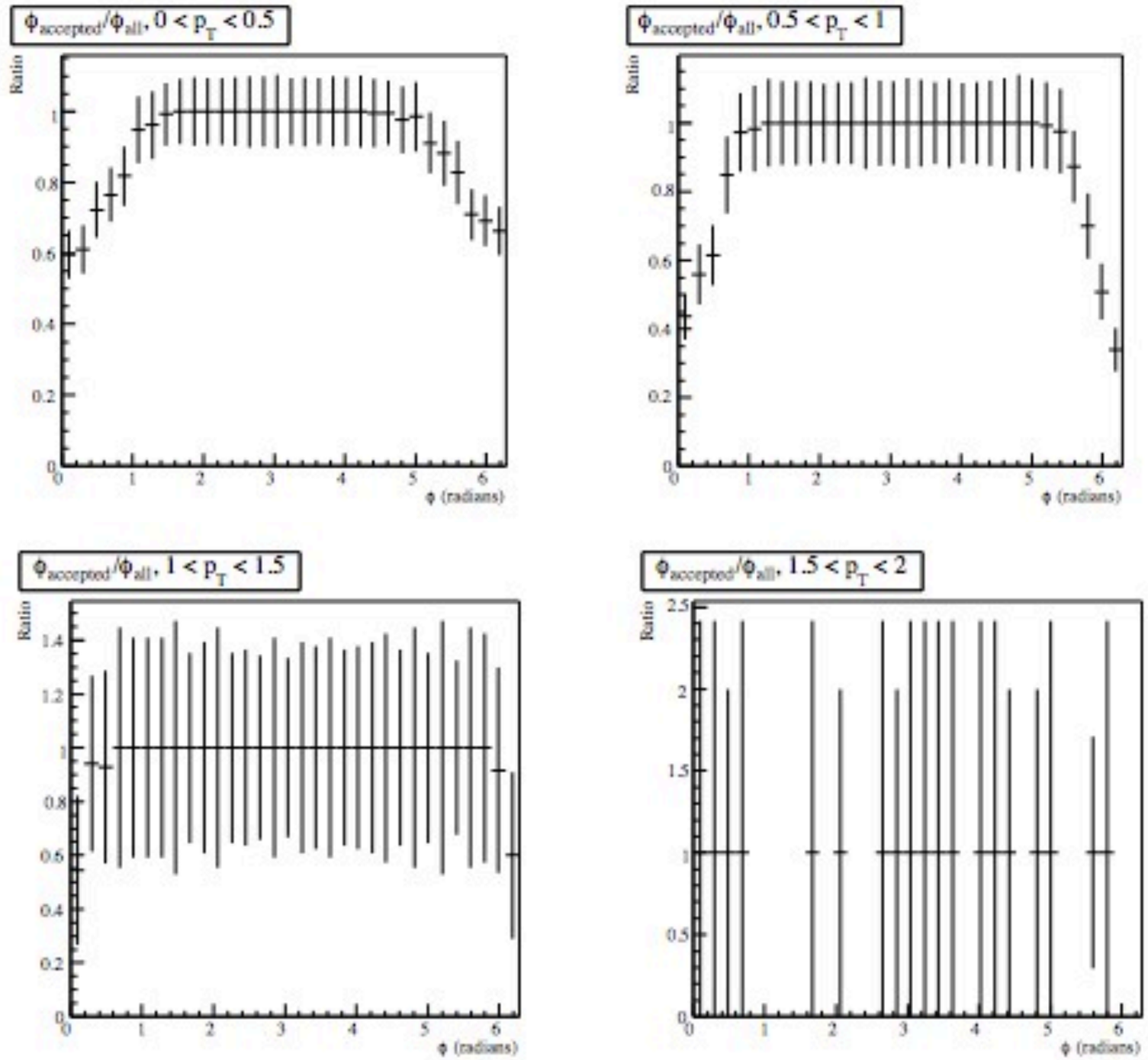
$0.8 < P_{h\perp} < 2$

Summary

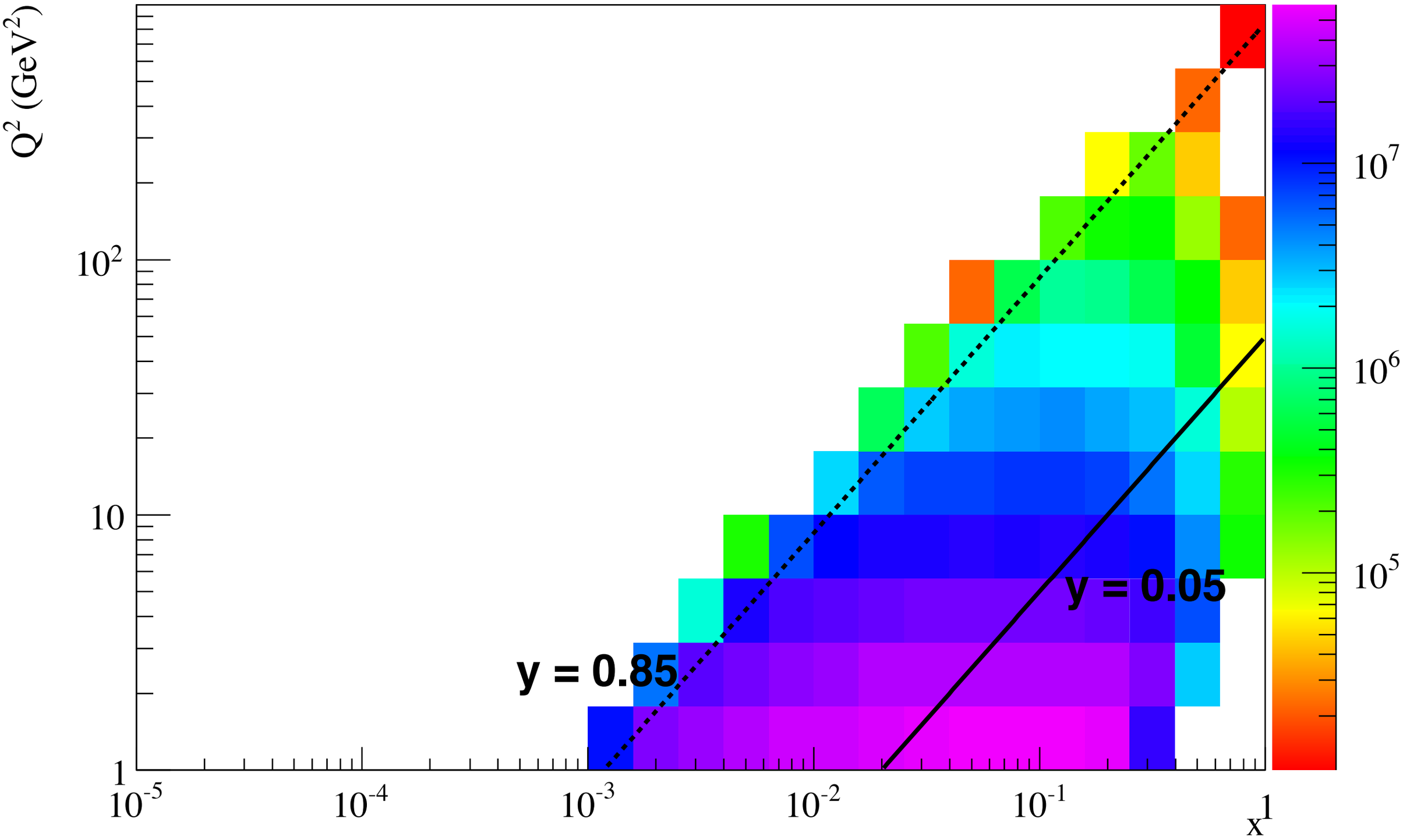
- Desire wide kinematic coverage
  - delivered by EIC designs
- High luminosity means:
  - High Q^2 (x, z, $p_{h\perp}$)-binning plausible
  - Low Q^2 rapidly systematics-dominated

Additional

5 x 50 ϕ_h acceptance



Q^2 vs. Bjorken x, 4 fb^{-1} at 5 x 50 GeV

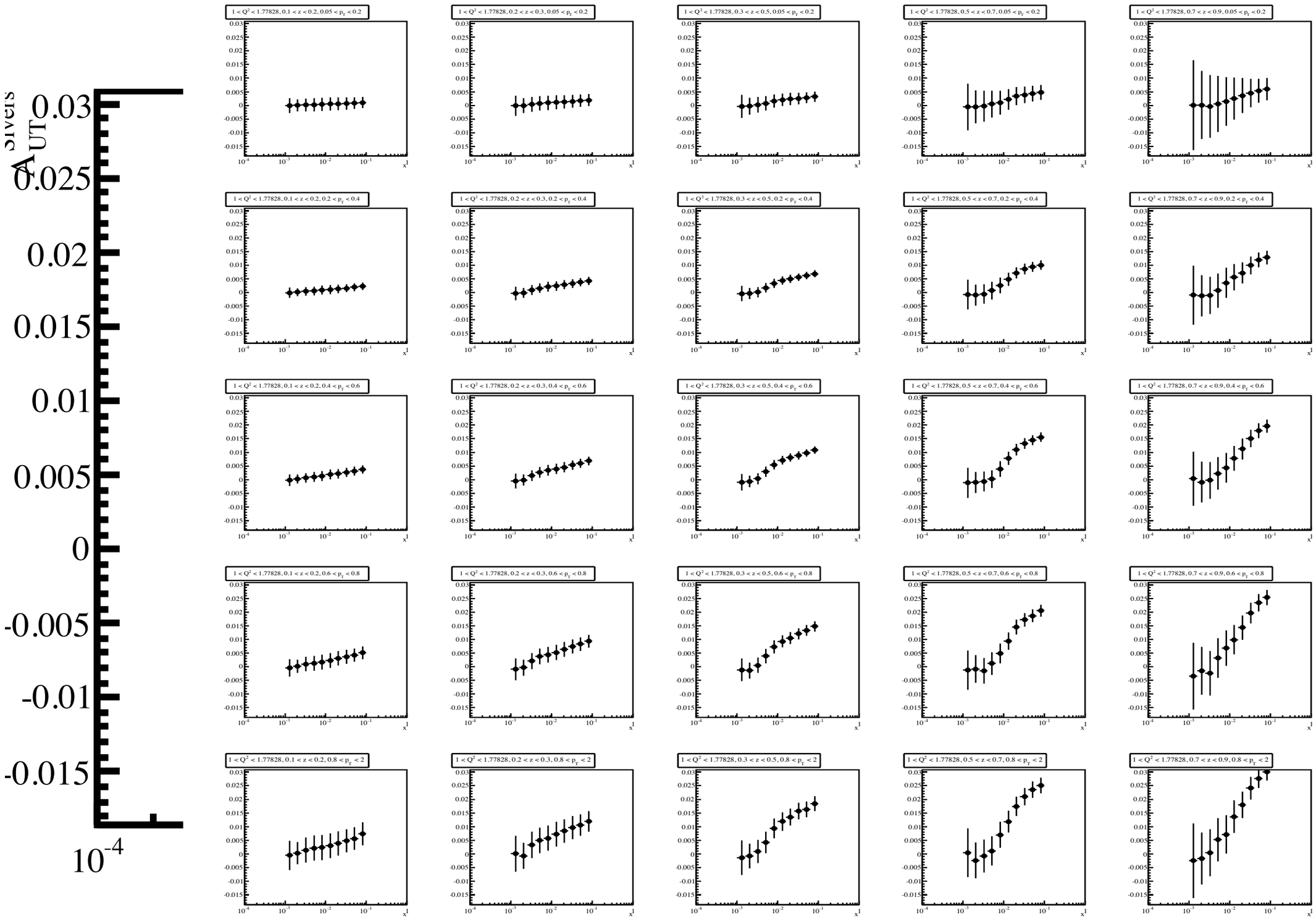


5 x 50 GeV

with positive sea

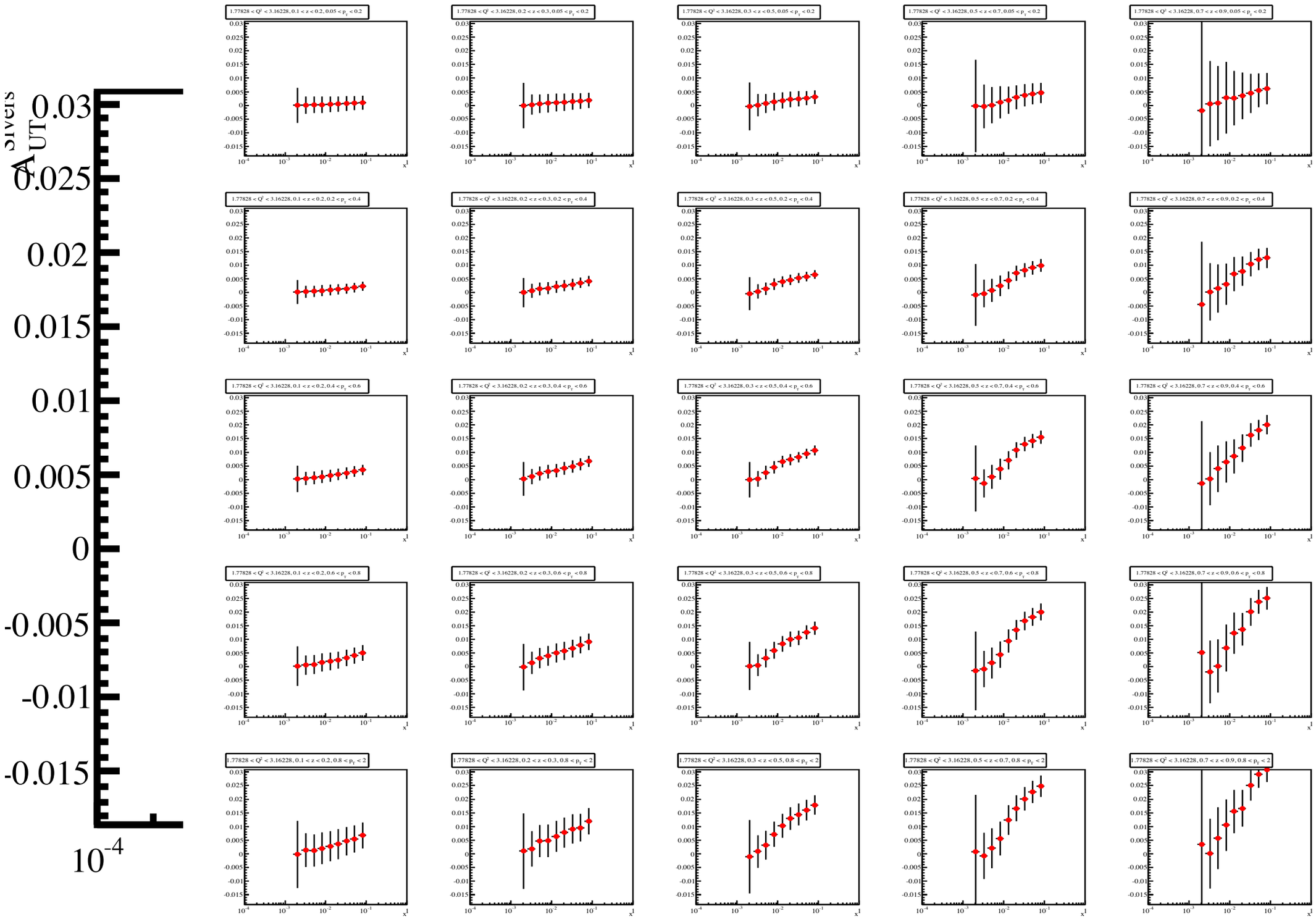
$1 < Q^2 < 1.78\ \mathrm{GeV}^2$

π^+



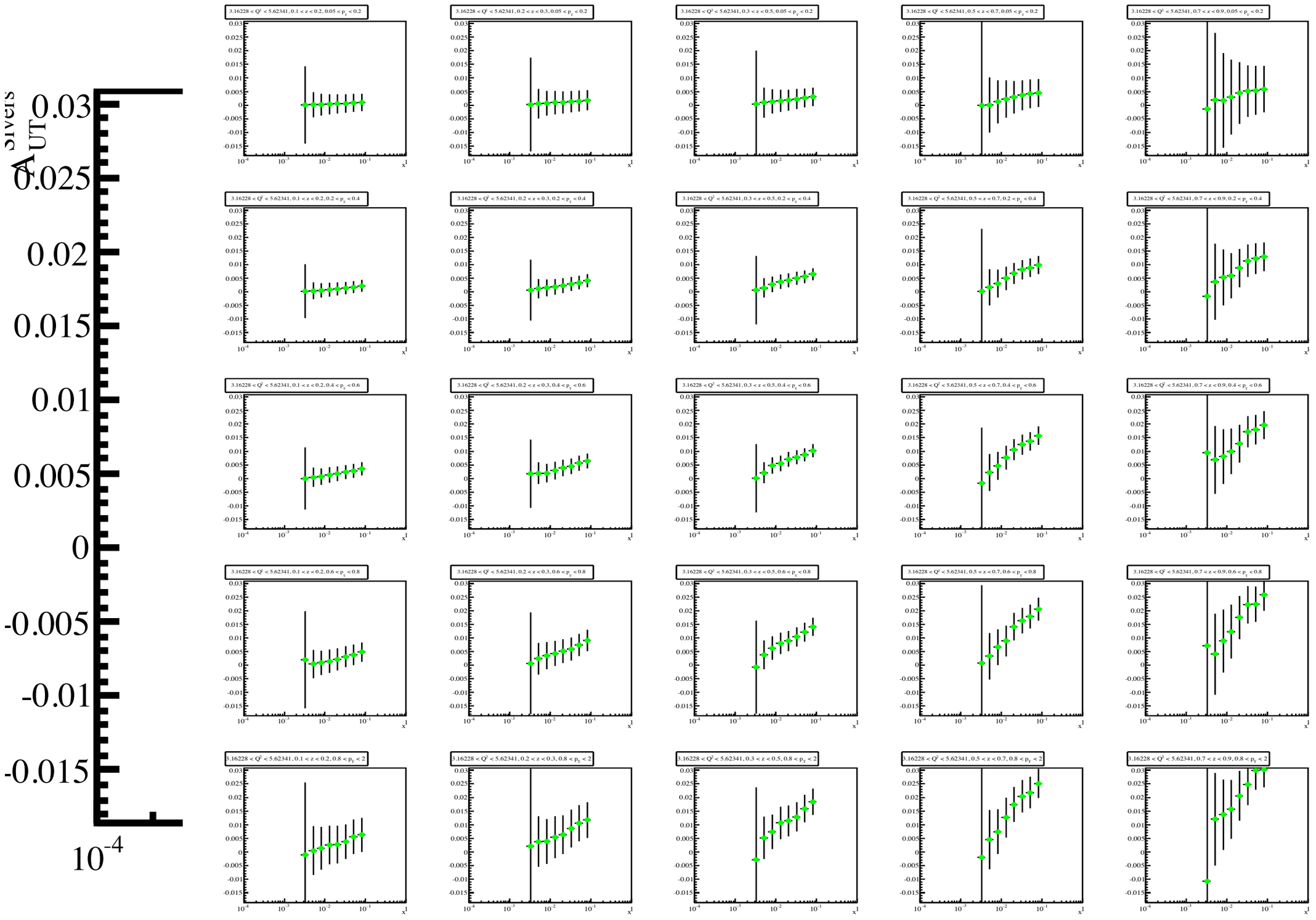
$1.78 < Q^2 < 3.16$ GeV^2

π^+



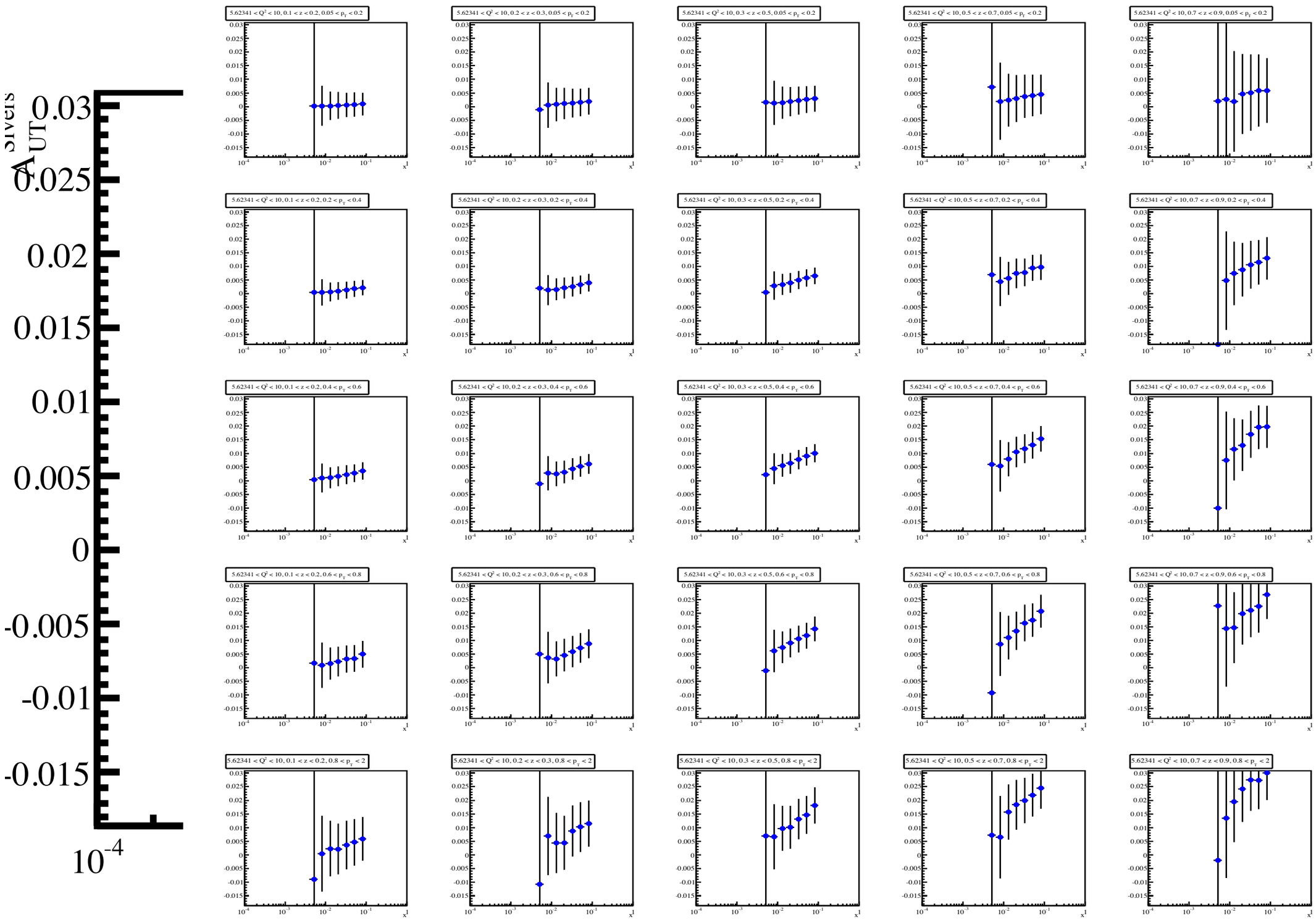
$3.16 < Q^2 < 5.62\ \mathrm{GeV}^2$

π^+



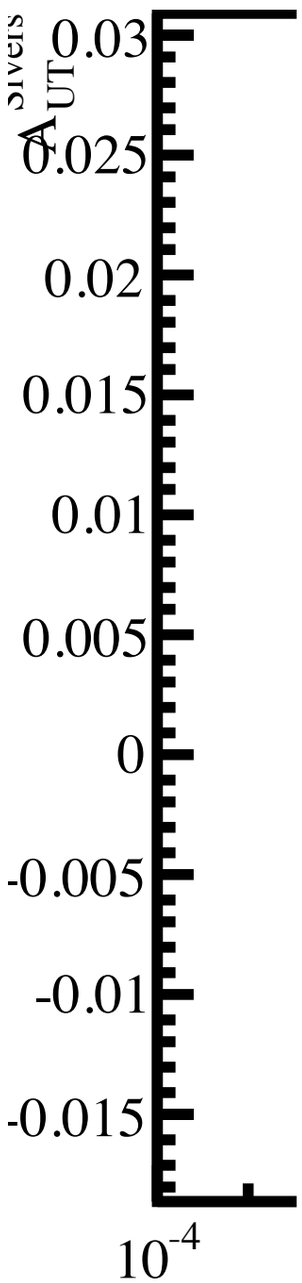
$5.62 < Q^2 < 10\ \mathrm{GeV}^2$

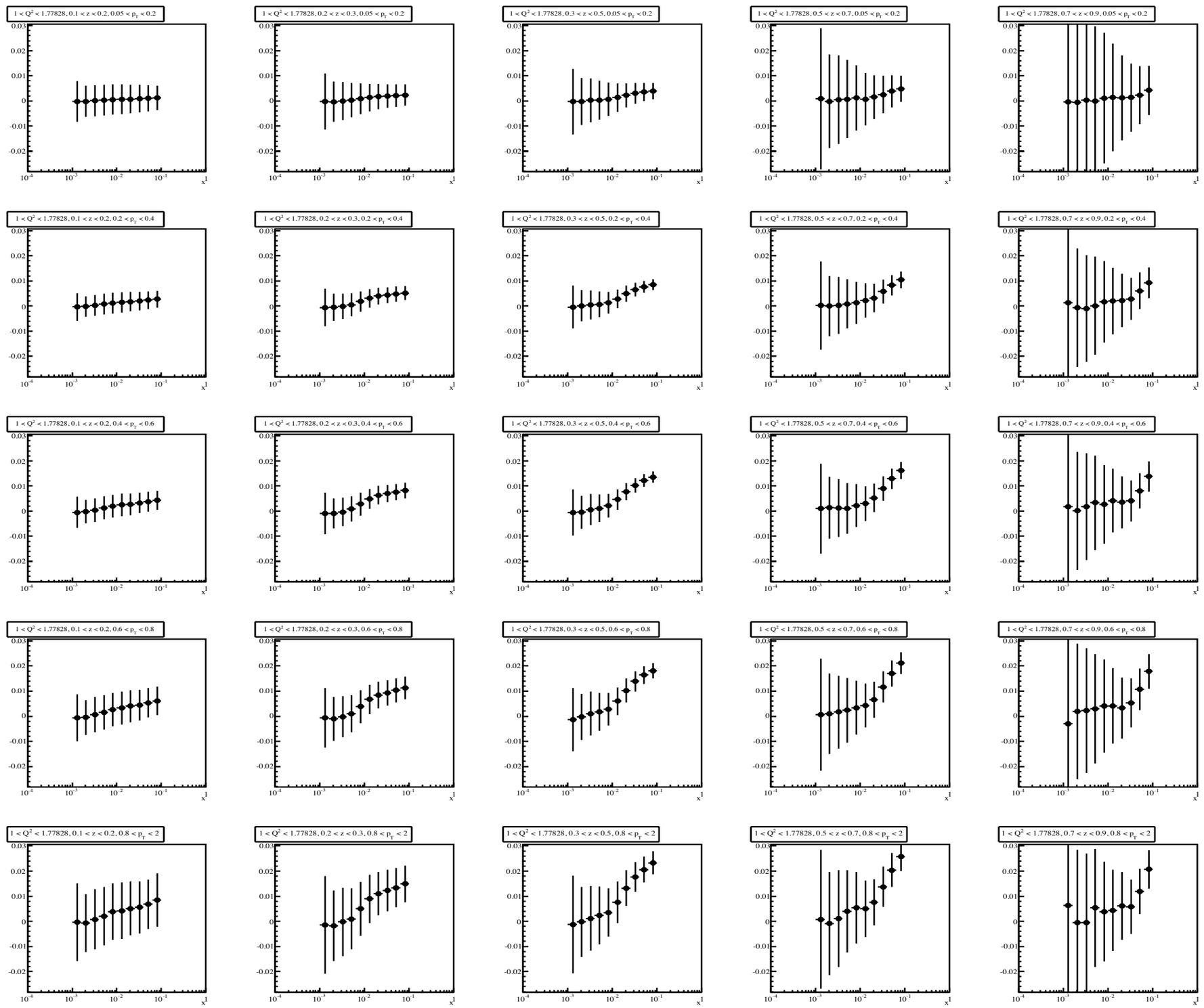
π^+



$1 < Q^2 < 1.78\ \mathrm{GeV}^2$

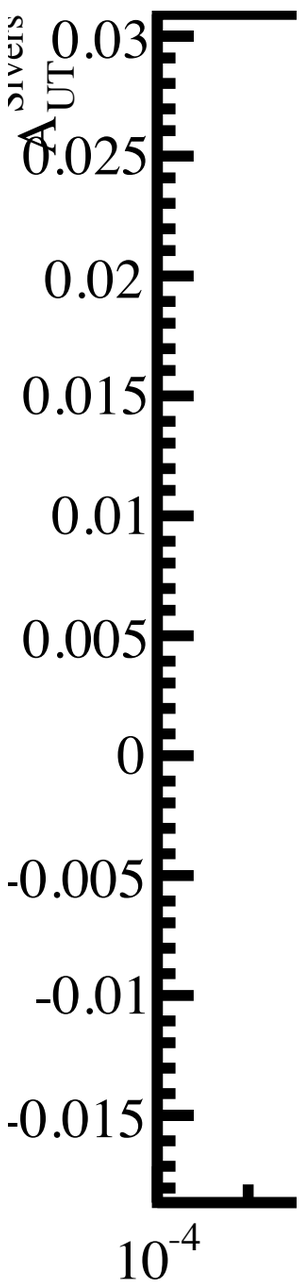
K^+

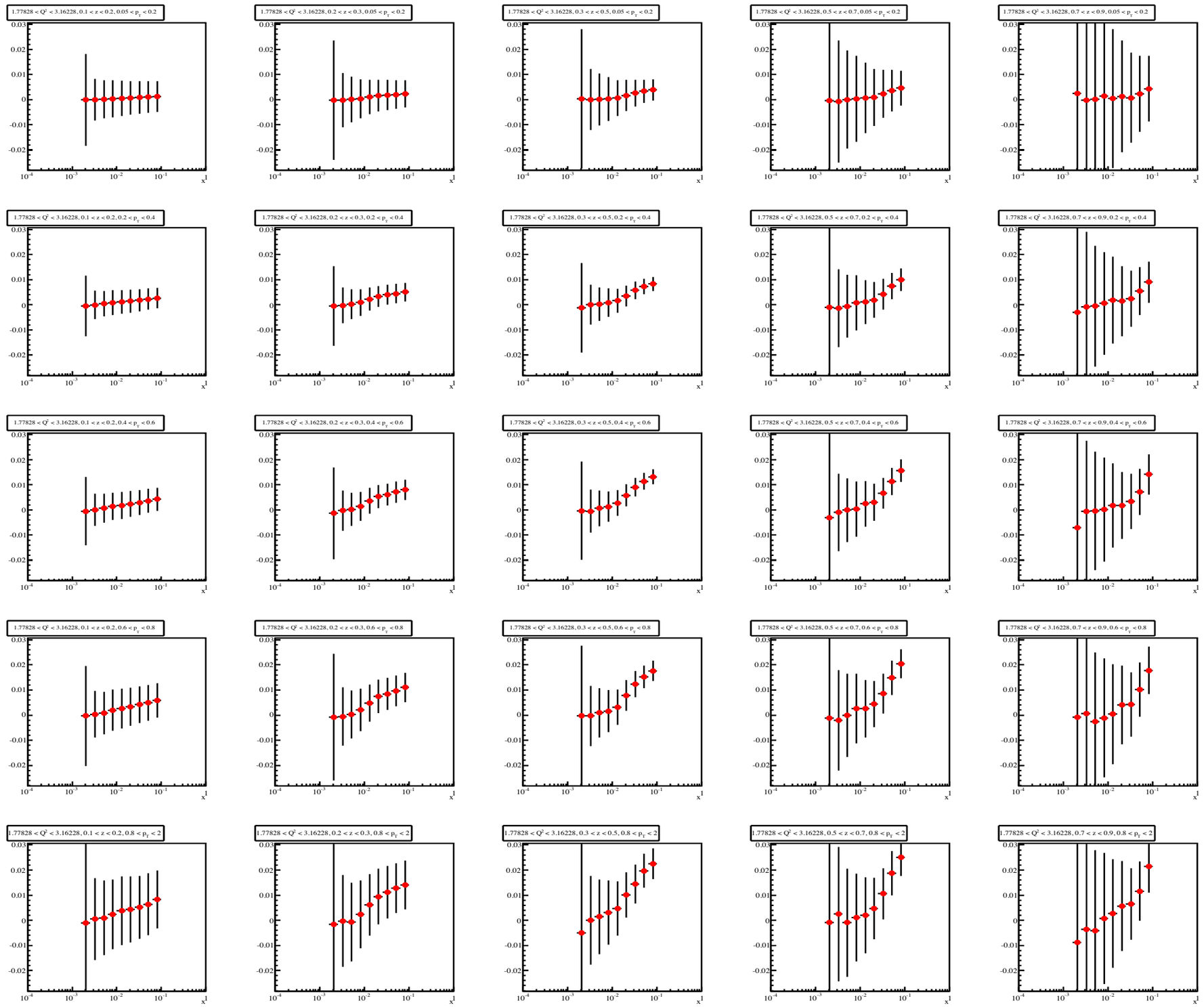




$1.78 < Q^2 < 3.16$ GeV^2

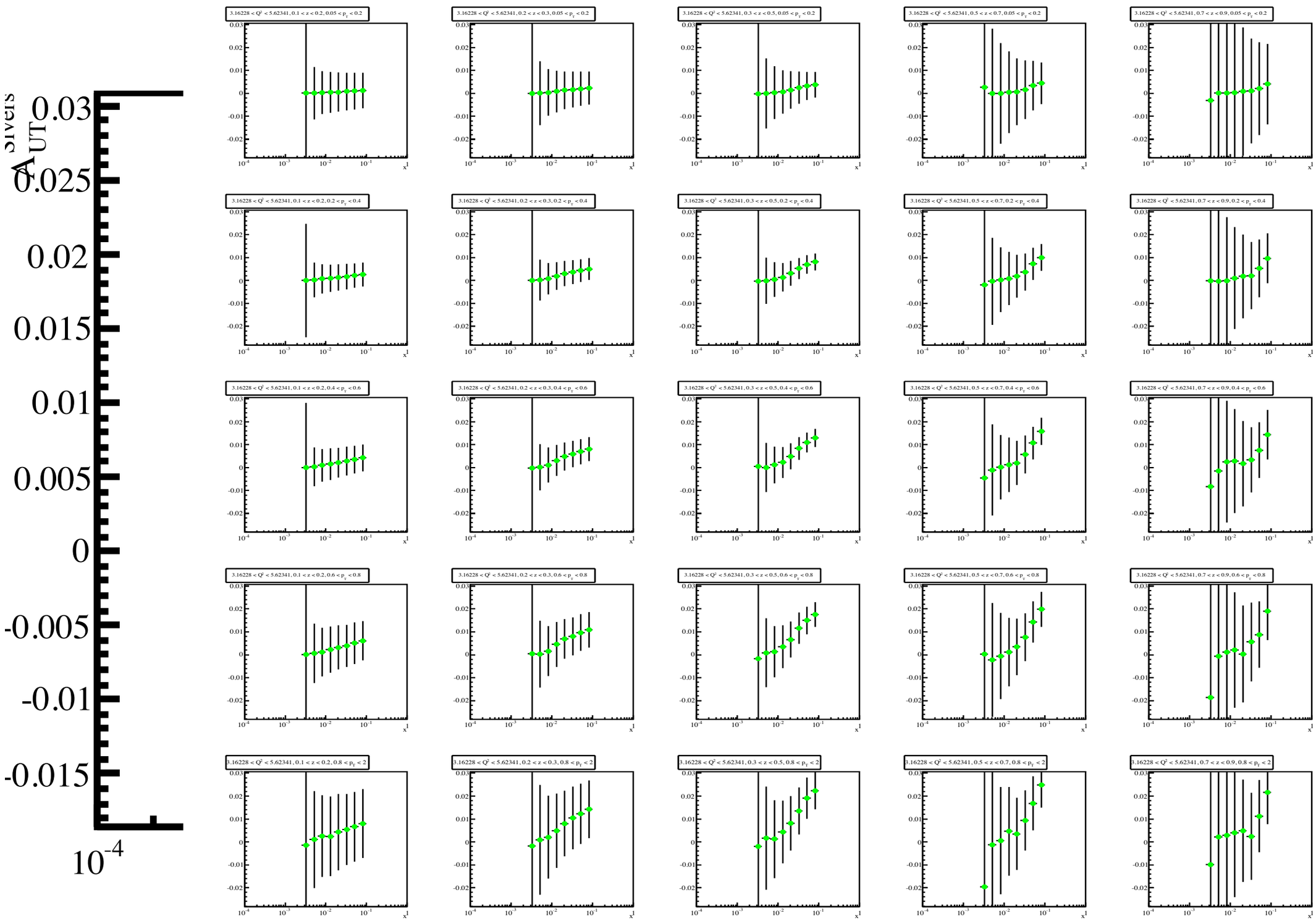
K^+





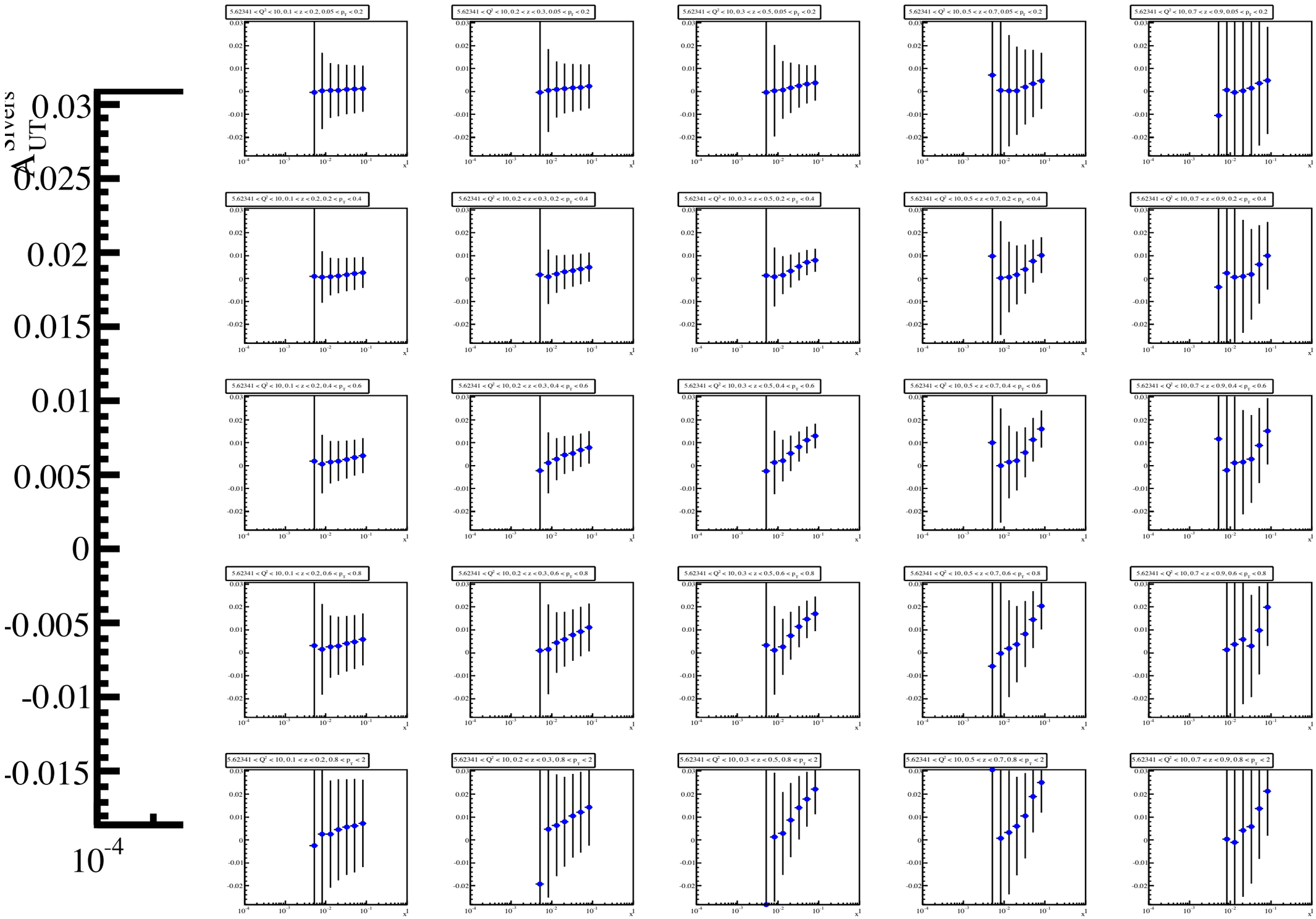
$3.16 < Q^2 < 5.62\ \mathrm{GeV}^2$

K^+



$5.62 < Q^2 < 10\ \mathrm{GeV}^2$

K^+

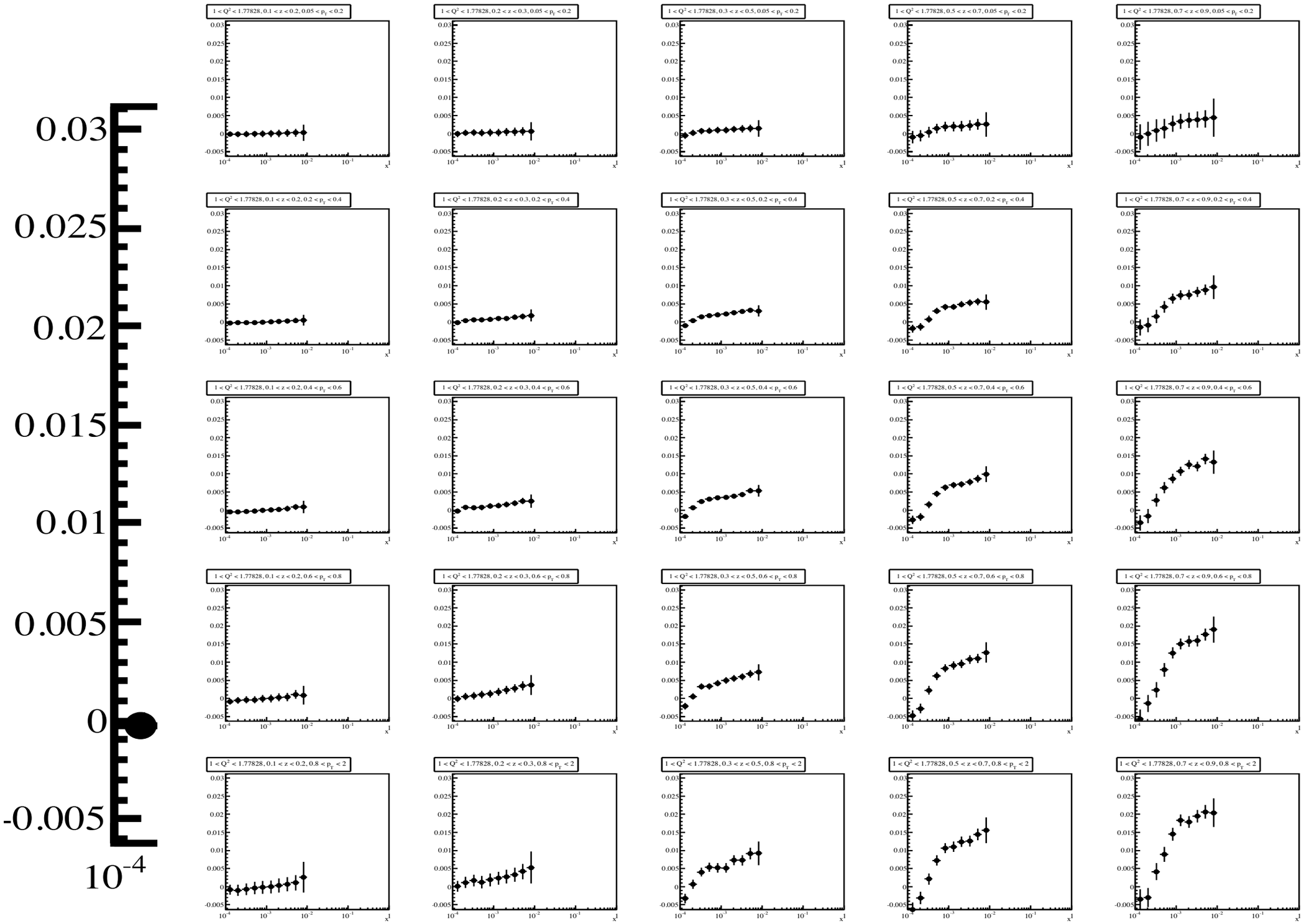


20 x 250 GeV

with positive sea

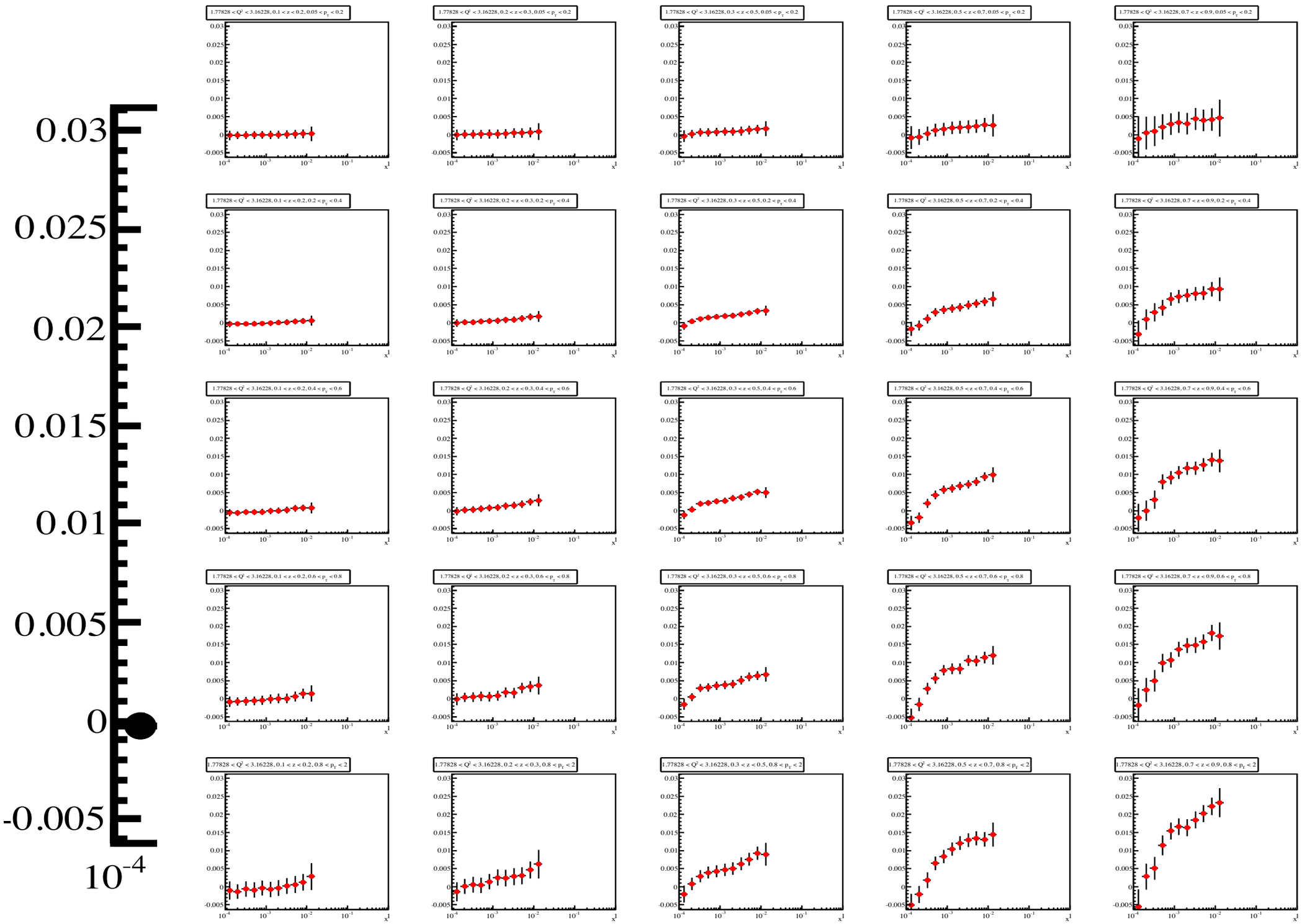
$1 < Q^2 < 1.78\ GeV^2$

π^+



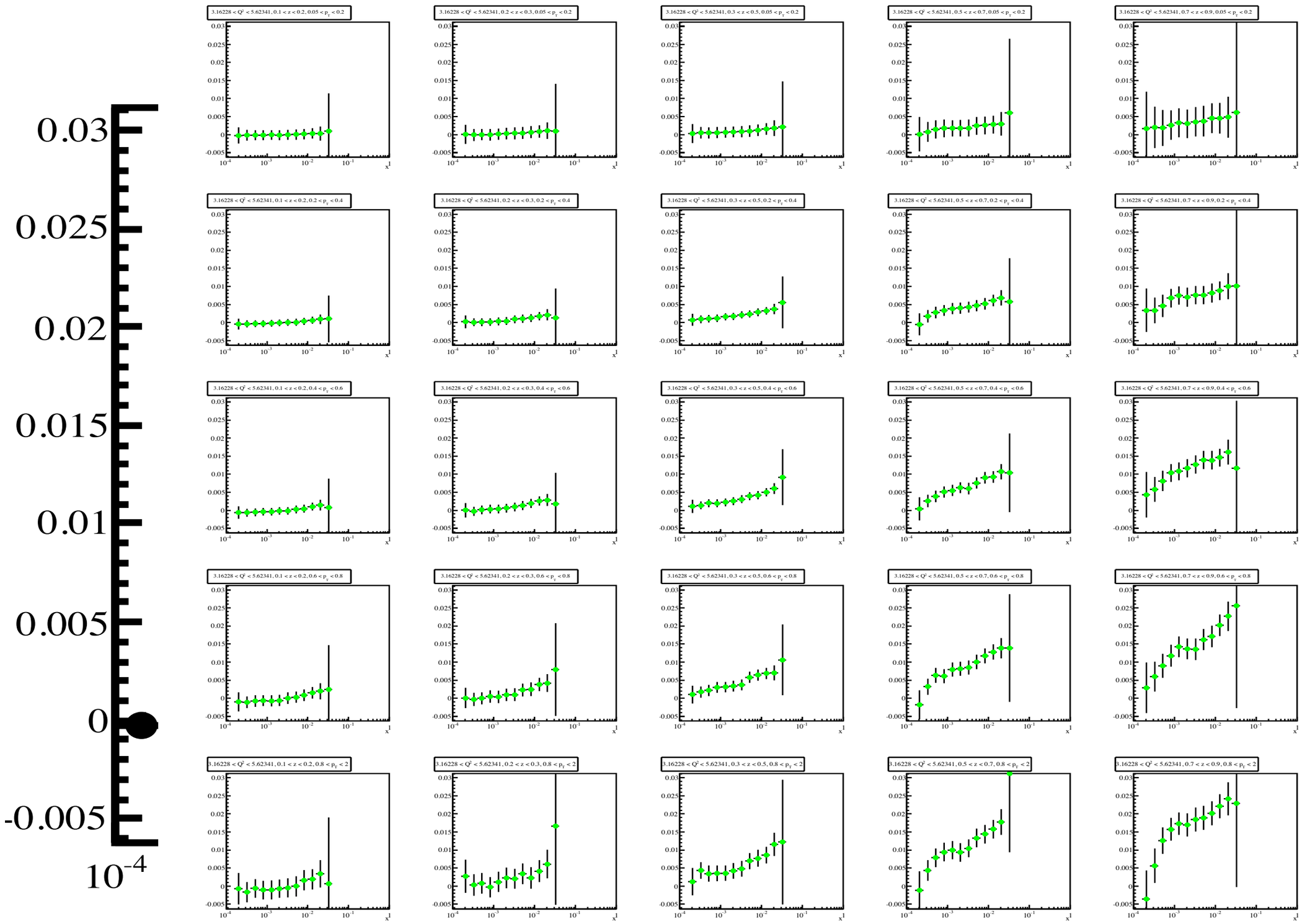
$1.78 < Q^2 < 3.16\ \mathrm{GeV}^2$

π^+



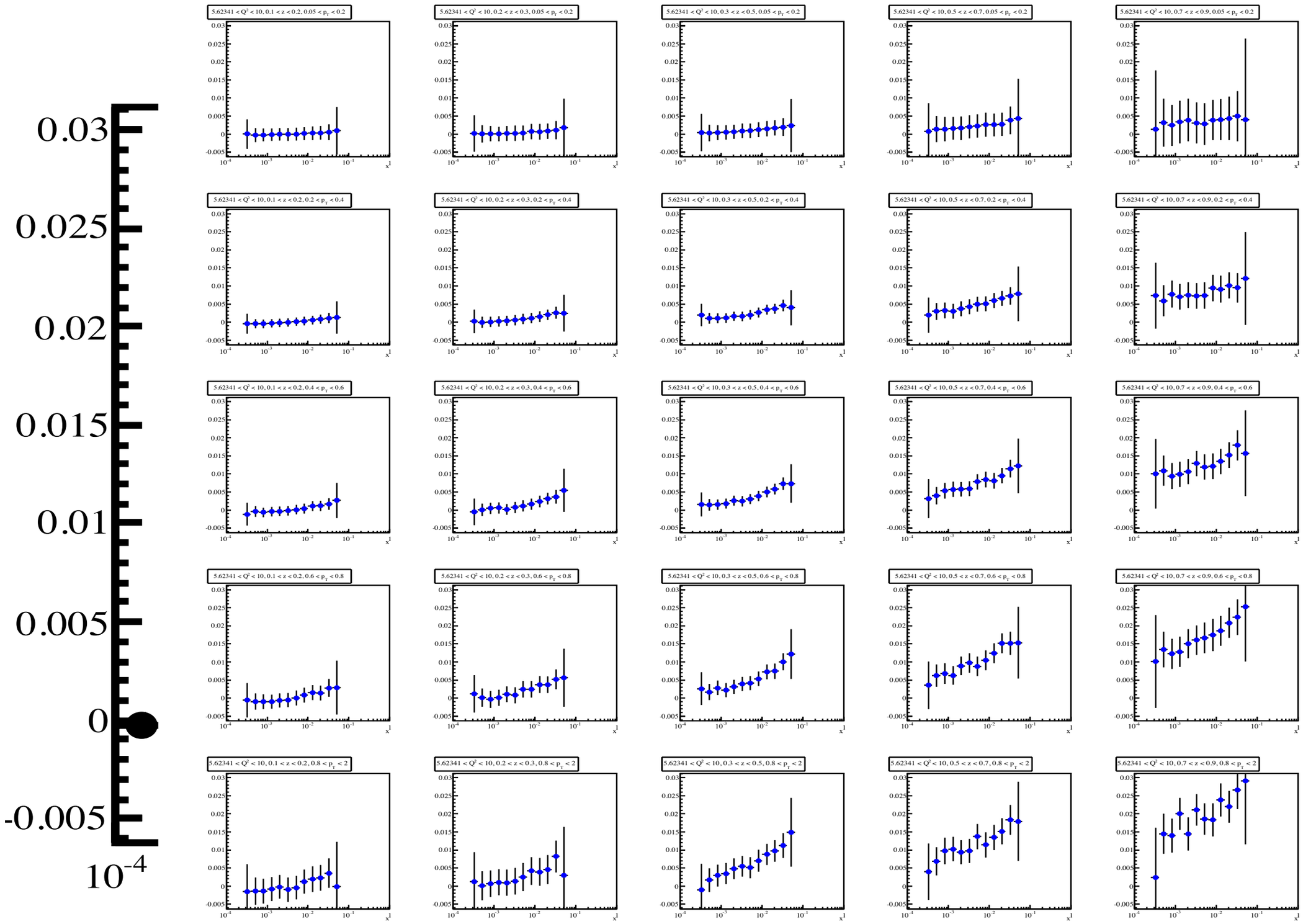
$3.16 < Q^2 < 5.62\ \mathrm{GeV}^2$

π^+



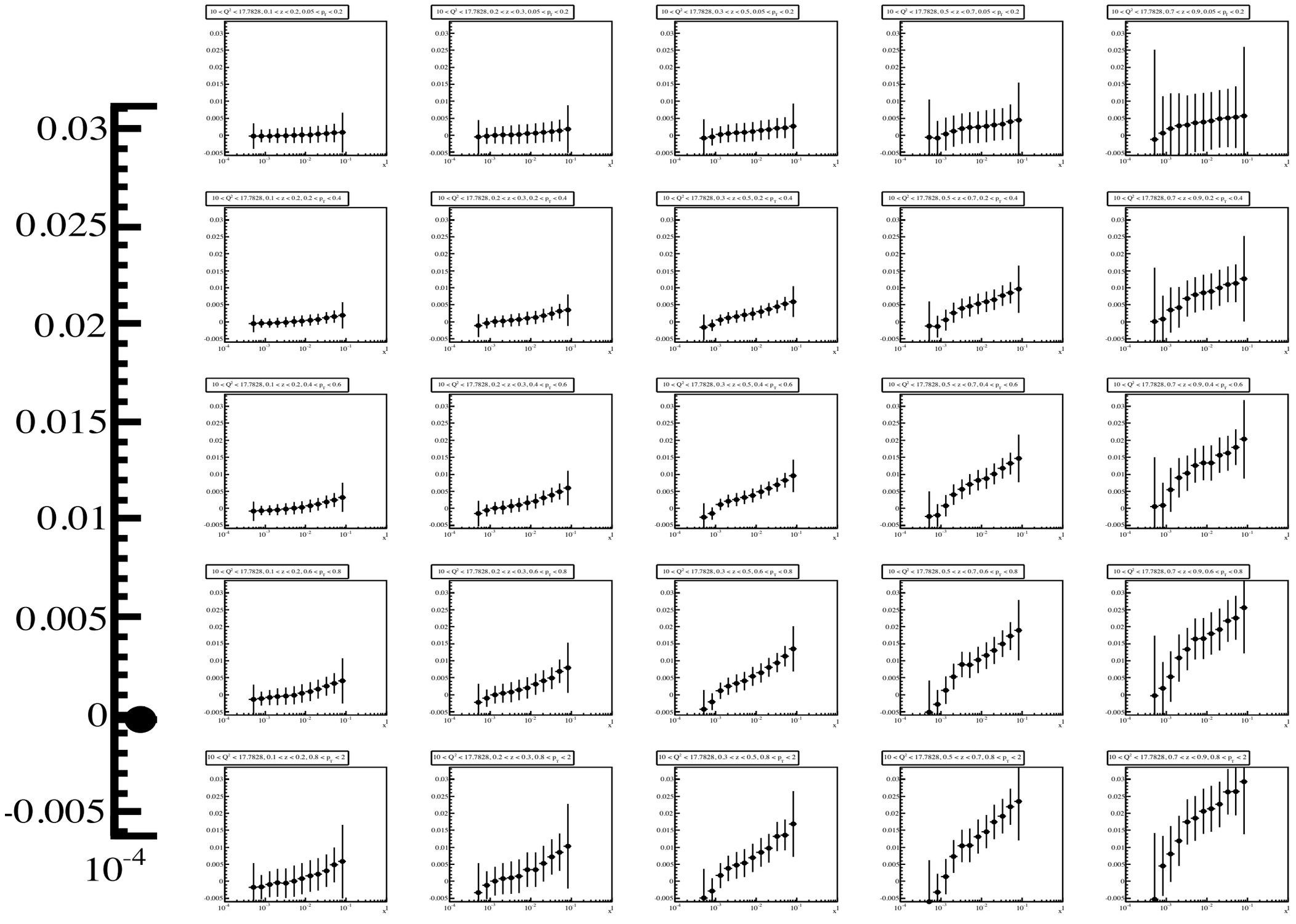
$5.62 < Q^2 < 10\ GeV^2$

π^+



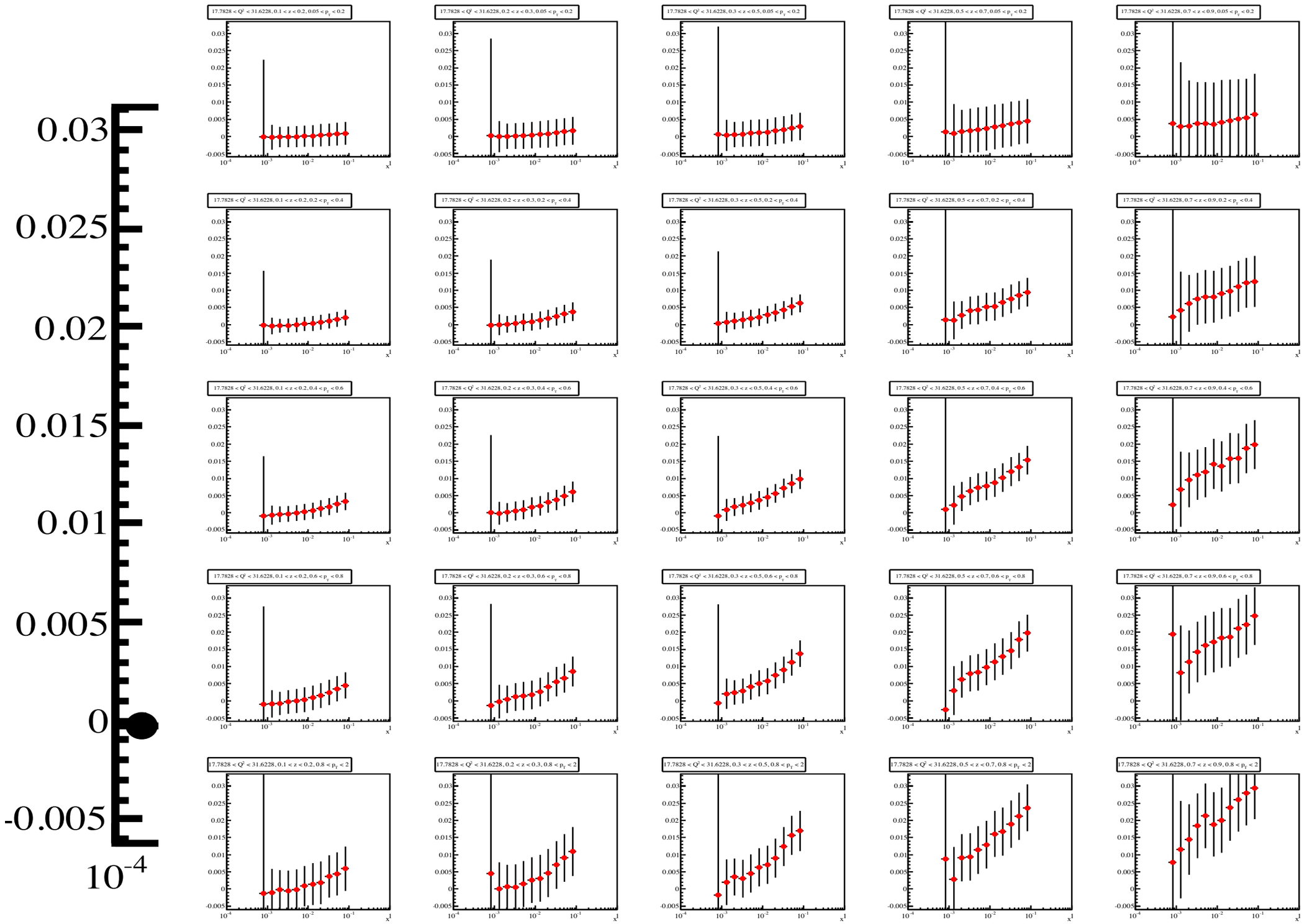
$10 < Q^2 < 17.8\ \mathrm{GeV}^2$

π^+



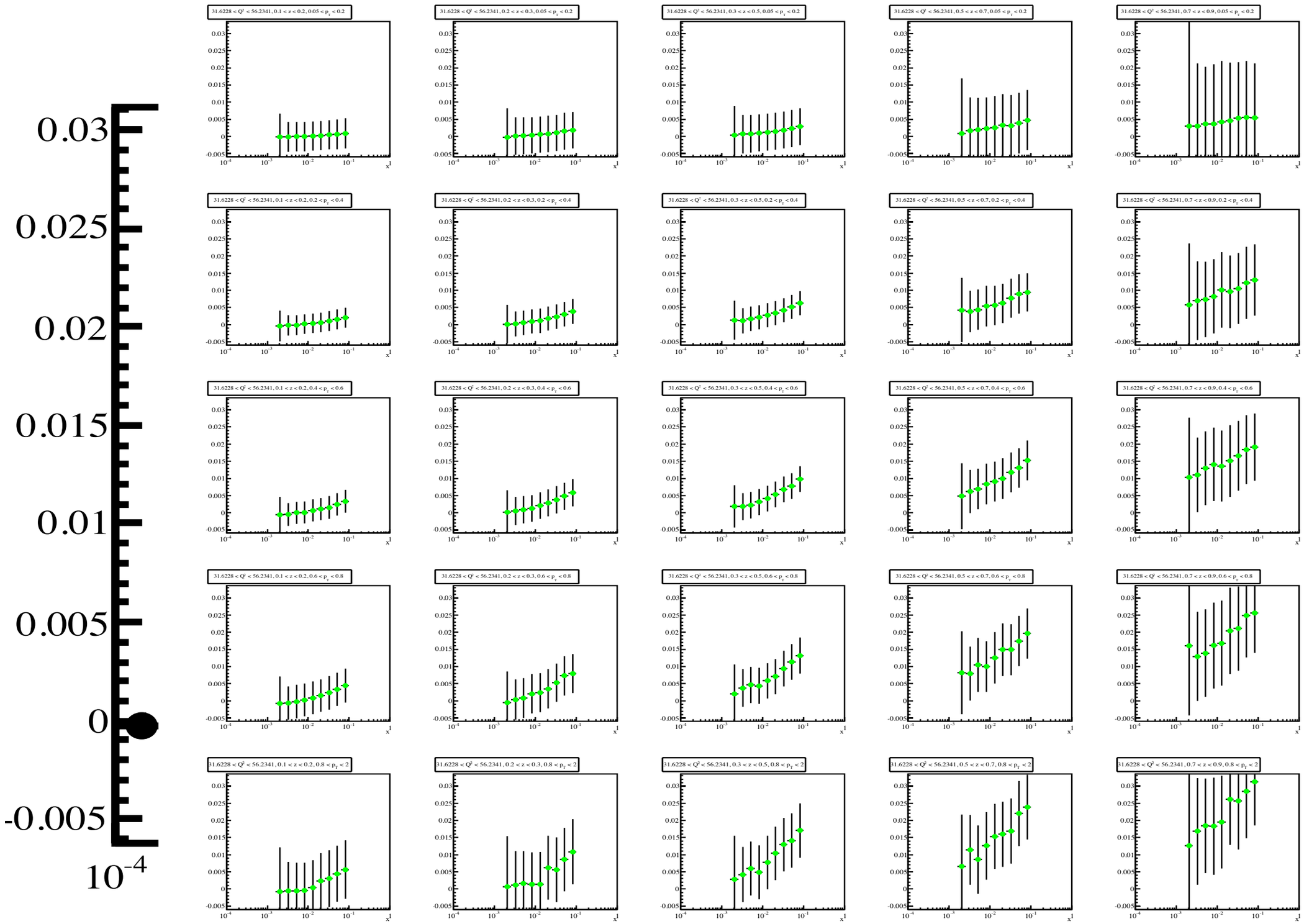
$17.8 < Q^2 < 31.6\ \mathrm{GeV}^2$

π^+



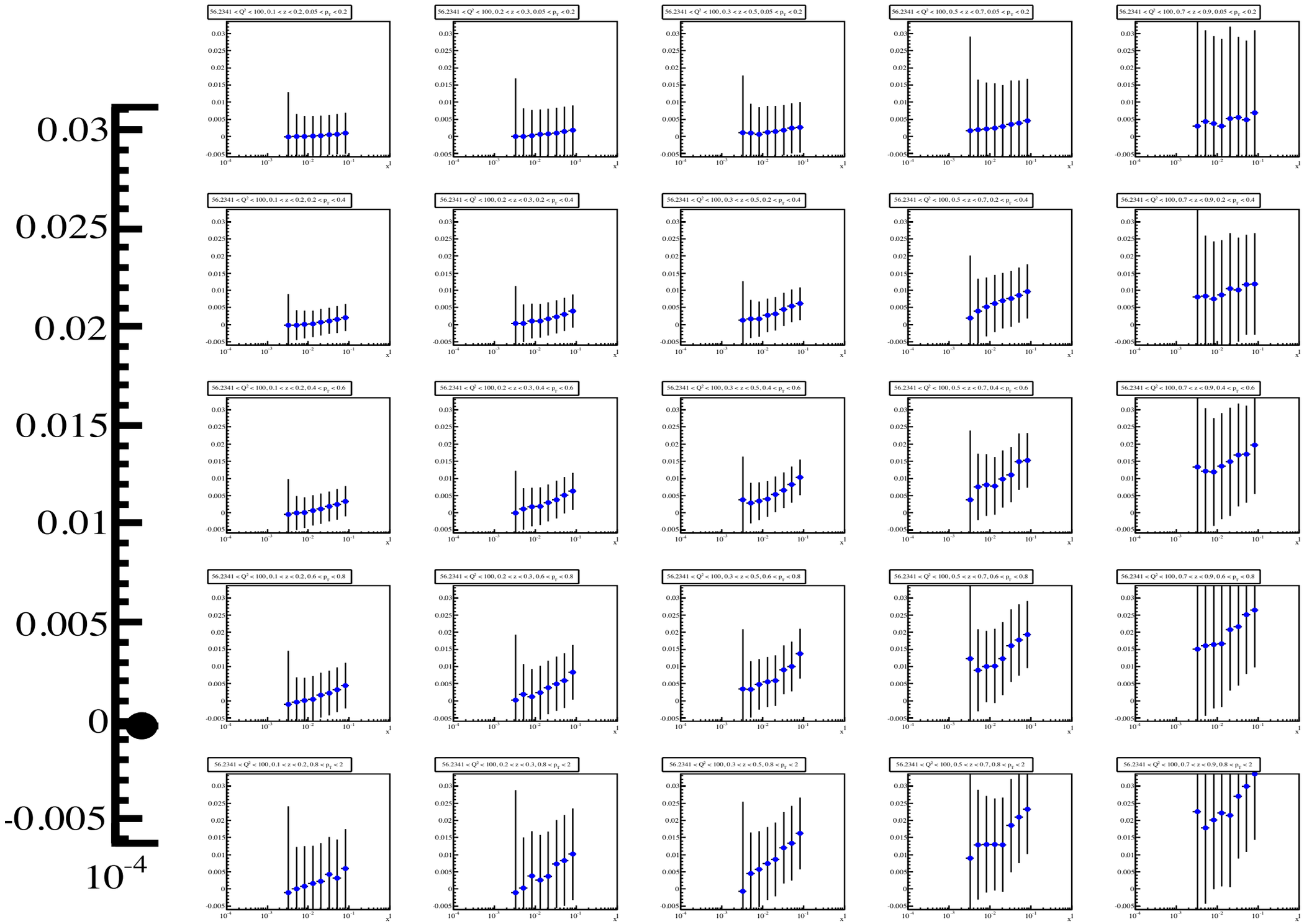
$31.6 < Q^2 < 56.2\ \mathrm{GeV}^2$

π^+



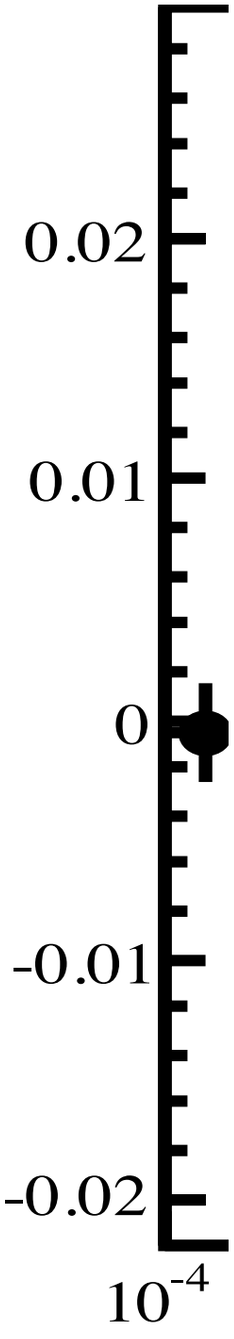
$56.2 < Q^2 < 100\ GeV^2$

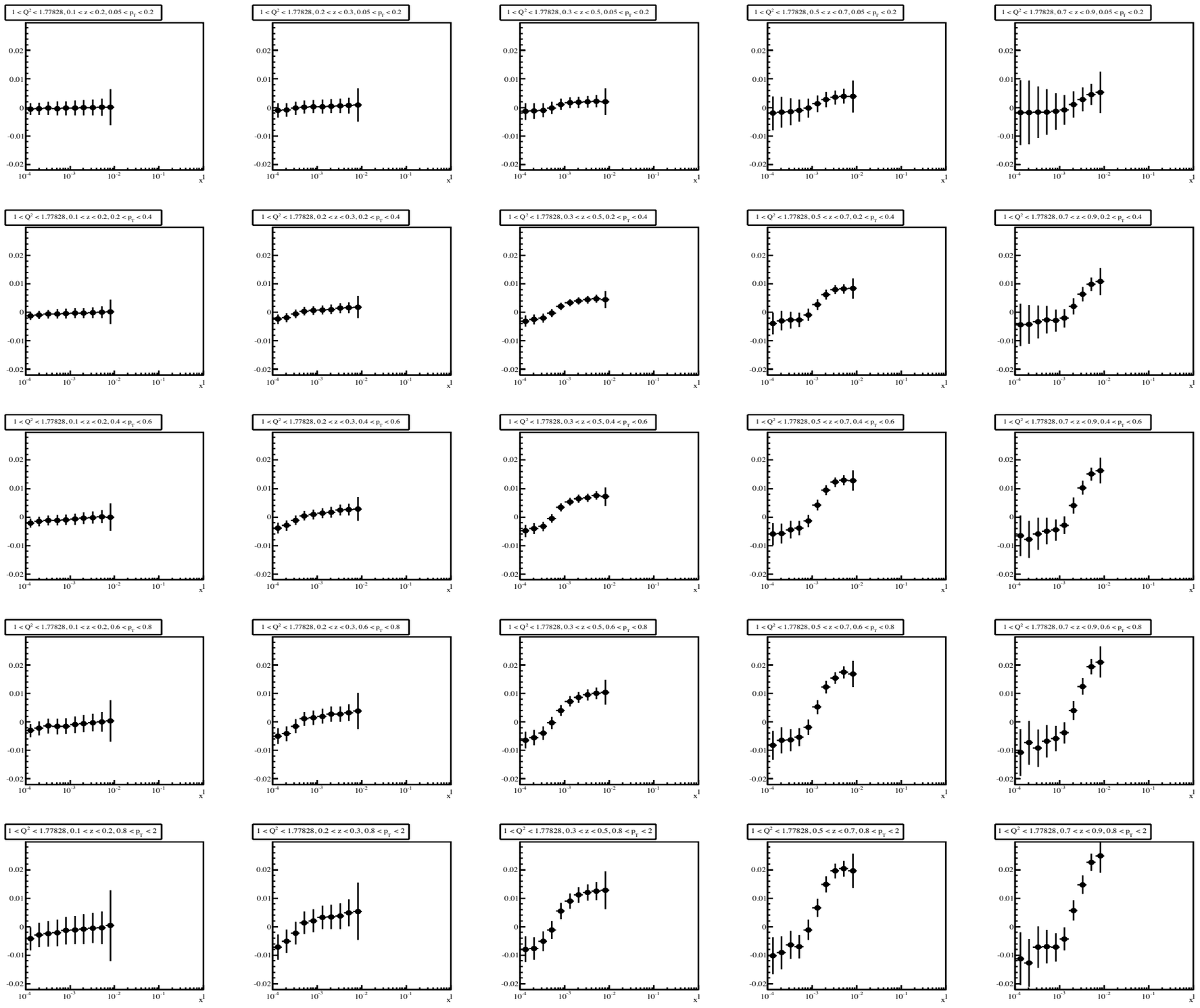
π^+



$1 < Q^2 < 1.78\ GeV^2$

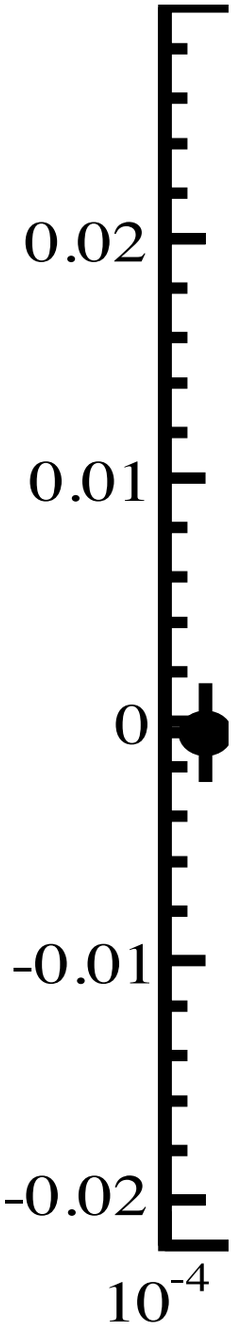
K^+

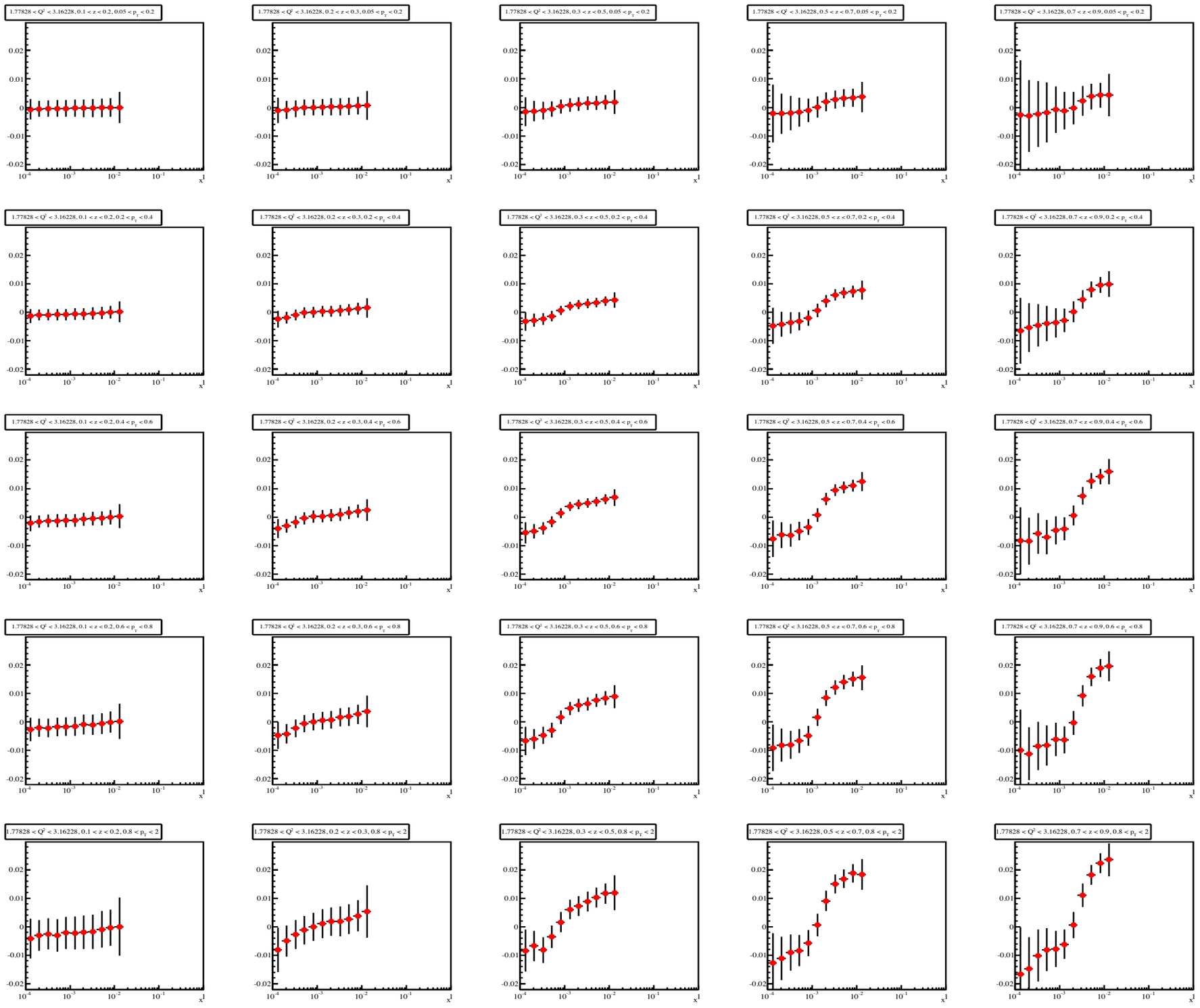




$1.78 < Q^2 < 3.16$ GeV^2

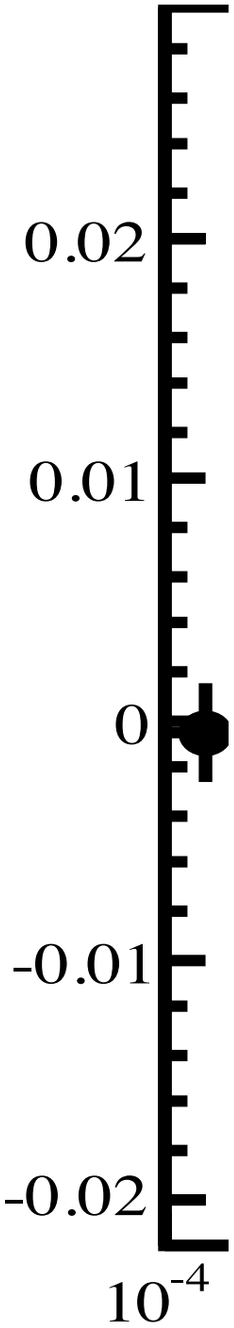
K^+

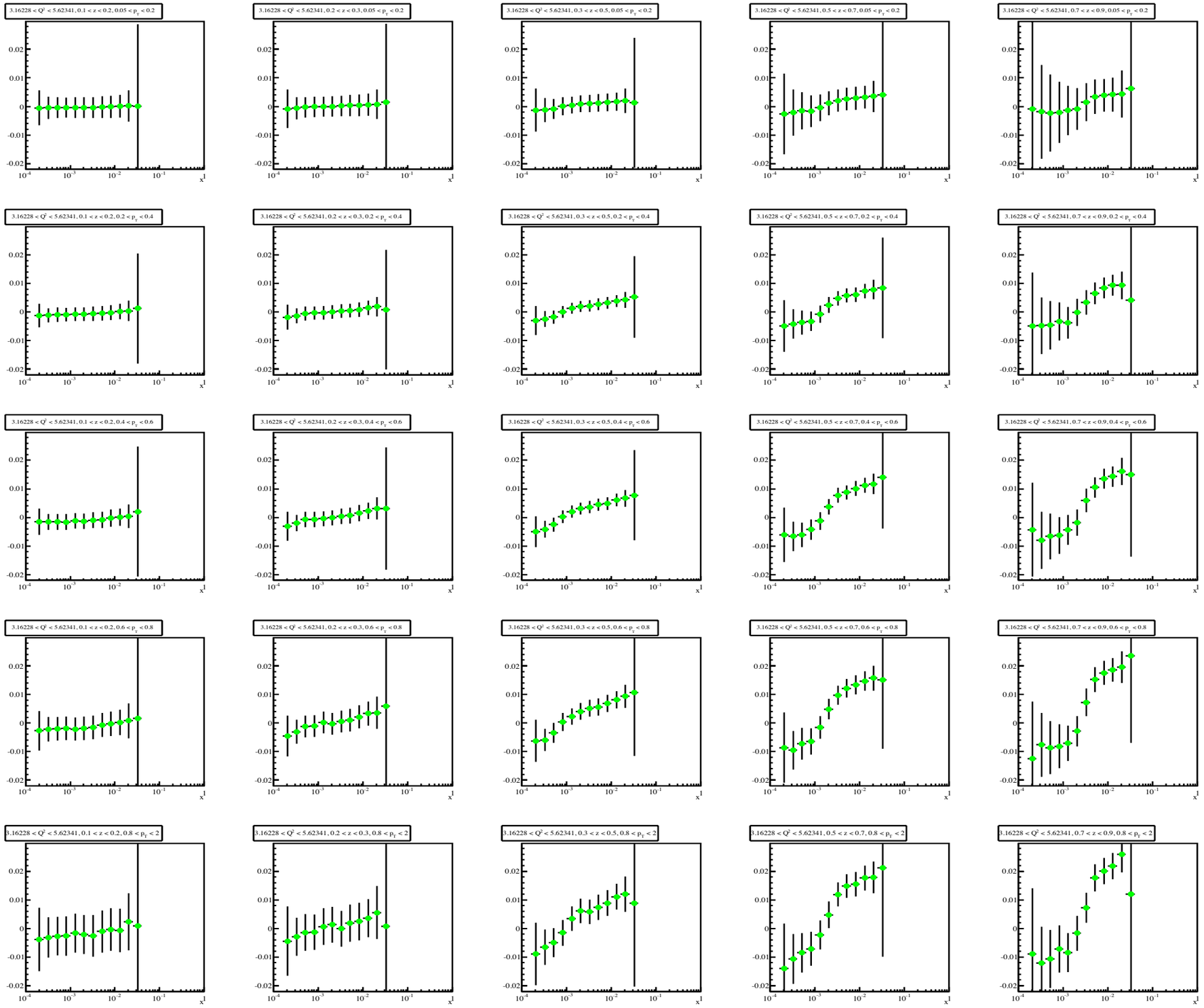




$3.16 < Q^2 < 5.62\ GeV^2$

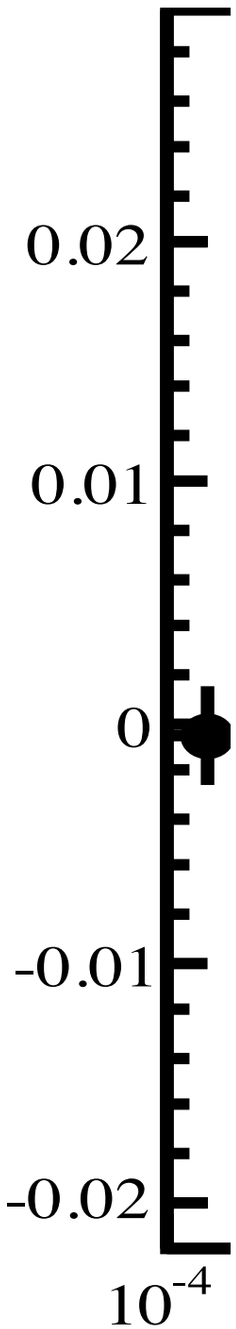
K^+

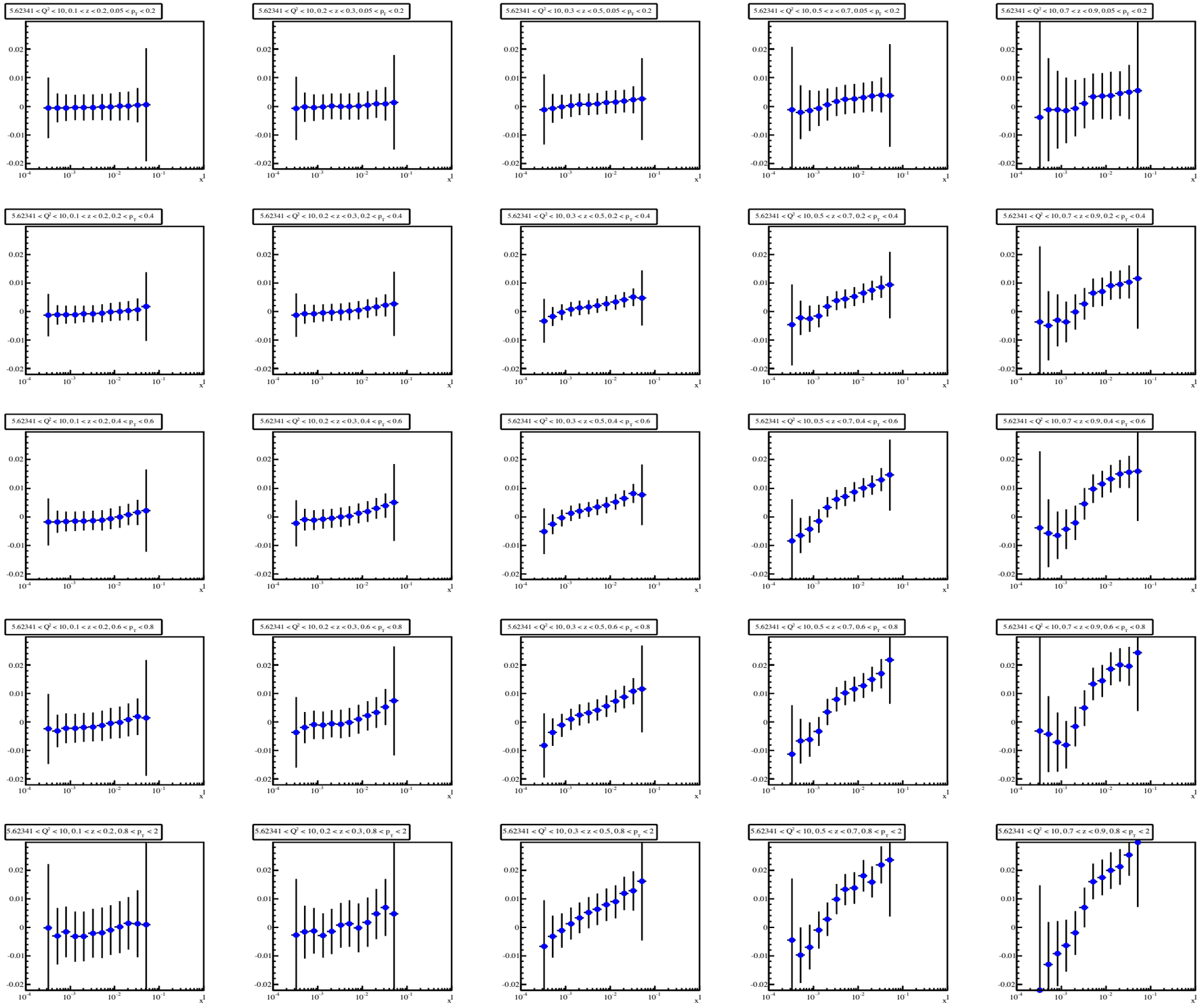




$5.62 < Q^2 < 10\ \mathrm{GeV}^2$

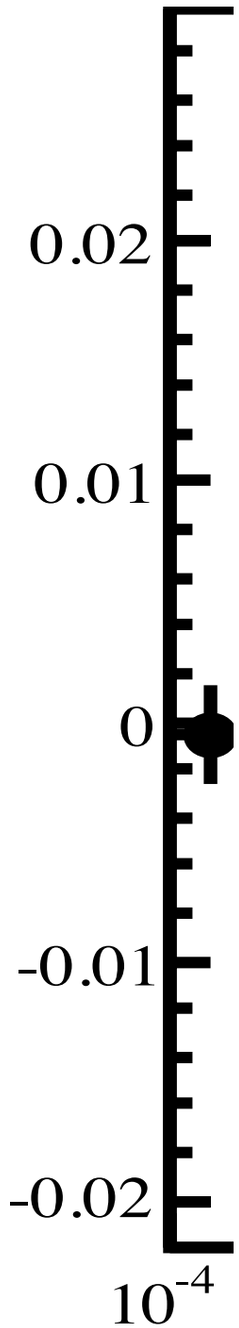
K^+

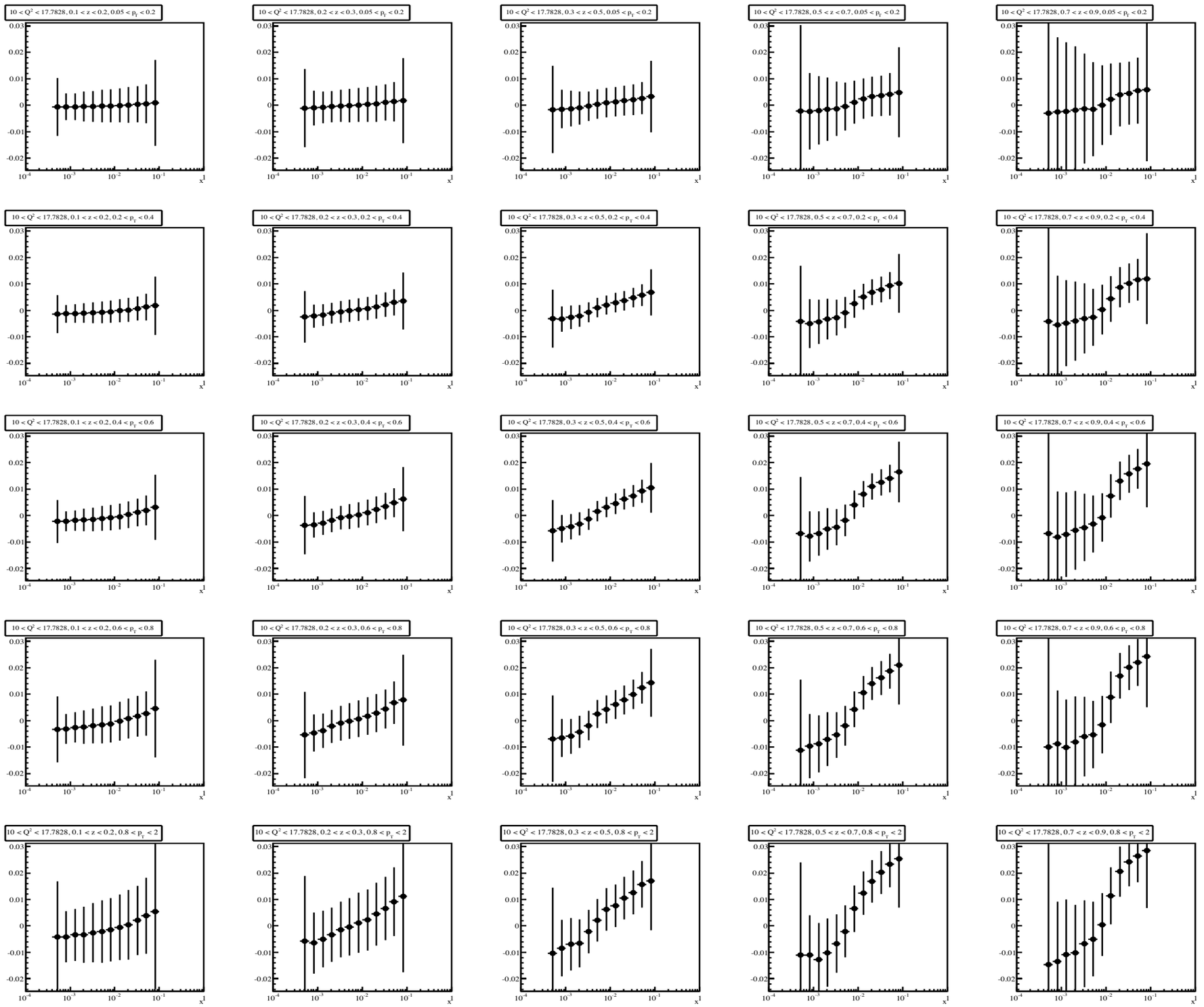




$10 < Q^2 < 17.8\ GeV^2$

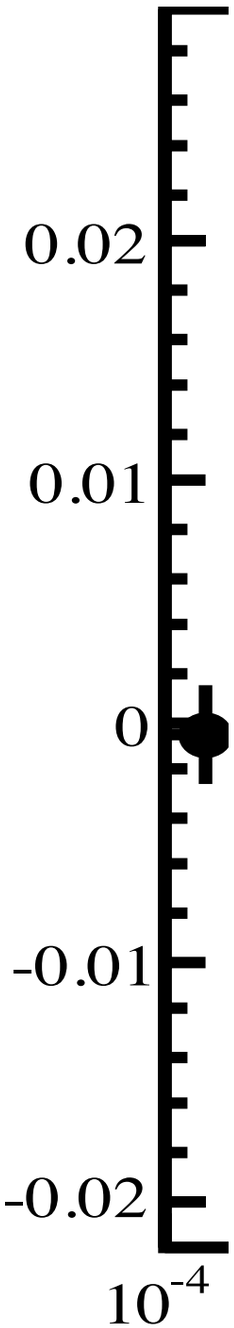
K^+

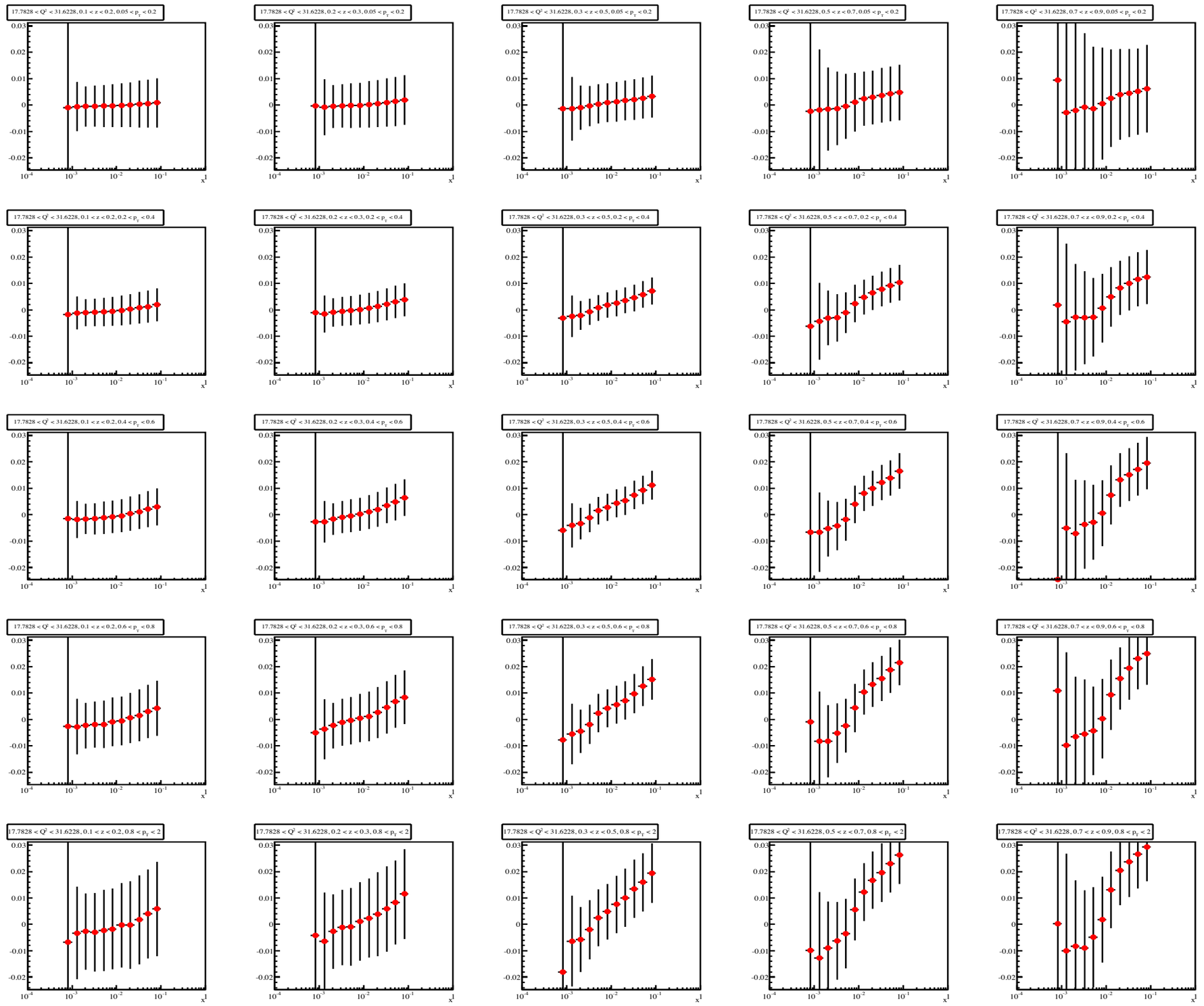




$17.8 < Q^2 < 31.6\ \mathrm{GeV}^2$

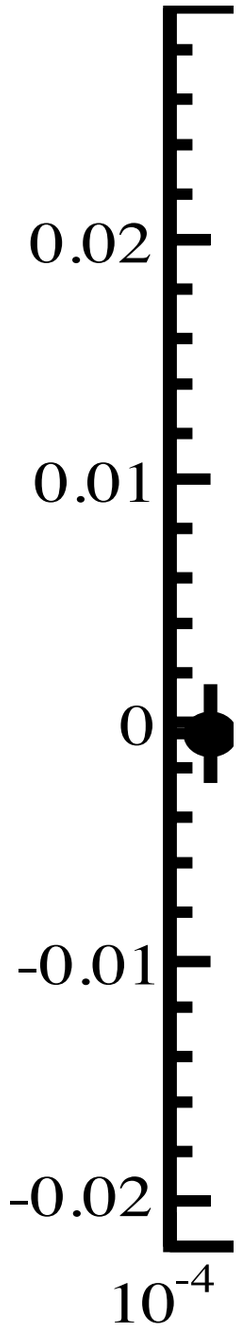
K^+

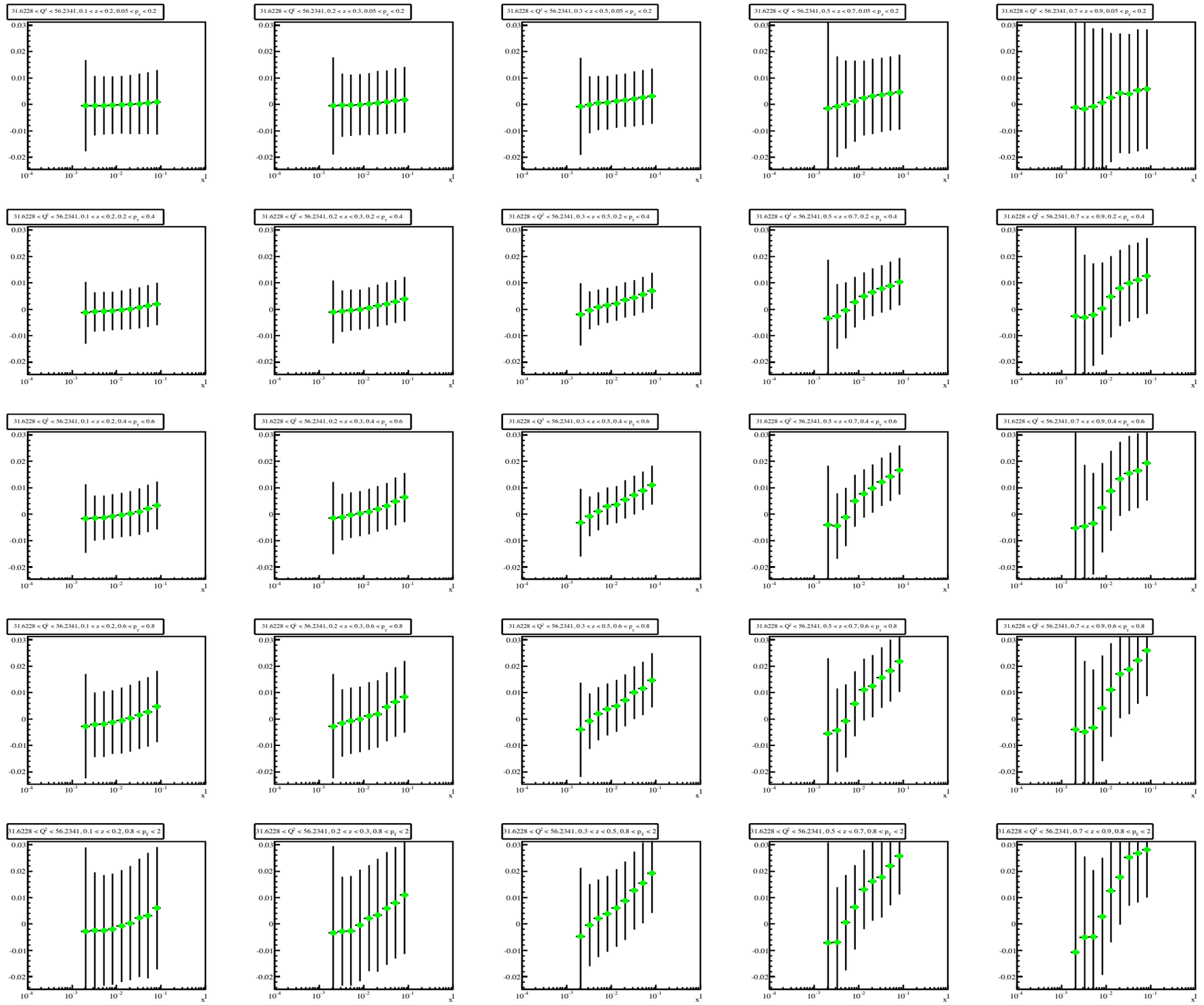




$31.6 < Q^2 < 56.2\ GeV^2$

K^+





$56.2 < Q^2 < 100\ GeV^2$

K^+